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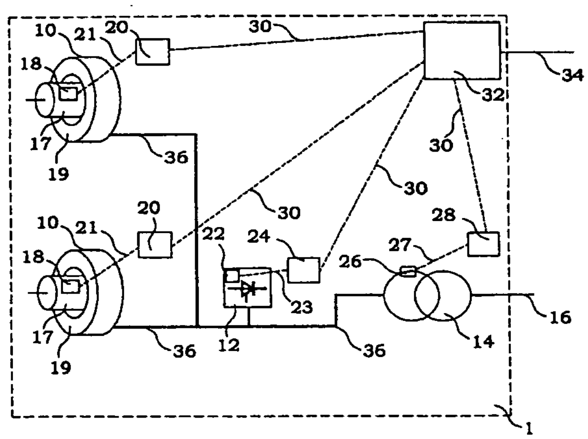
(54) Title: ELECTRIC POWER SUPERVISION



(57) Abstract: The present invention utilises direct measurement of marginal critical quantities in direct connection to interesting points in electric power processes in the different electric power objects (10, 12, 14). These points are generally located at places difficult to access, such as on high potential, or at rotating parts (17). The measurements give direct information about actual, now valid operational margins, concerning marginal critical quantities and in particular for quantities that is both marginal critical and material critical. Data about available margins is transferred to other units (32) within the network or plant (1). The electric power plant (1) or electric power network can then be controlled based from such actual operational margins from several different units (10, 12, 14) in the plant (1), which enables a more efficient operation of the plant (1) or network. The measurements give further new paths for detecting faults in the systems. Furthermore, databases of operational conditions can be built, which then can be used both as support for the operation of the system as well as for future maintenance, model building etc.

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ELECTRIC POWER SUPERVISION

TECHNICAL FIELD

The present invention generally relates to supervision and control of electric power plants and electric power networks. The invention relates in particular to determination of actual operational margins for electric power objects or electric power units that are included in the electric power plant or electric power network.

BACKGROUND

Supervision and control is used within the electric power area as designation of measurement value collection, remote supervision and remote control of electric power systems. Electric power networks constitute complex technical systems that often cover large geographical areas, which often lead to a need for advanced systems for supervision and control of these networks. There was early a need for introducing central control rooms, so-called control centres, from which the operators could form an opinion about what was happening out in the different parts of the electric power network. The condition in the network can be estimated by functions for topology handling and state estimation. During the last decades, there have furthermore been considerable interconnections of the regional networks to large interregional electric power systems, which can cover very large geographical areas. The development of larger and increasingly complex electric power systems has resulted in increasing demands on data collection, data processing and control and supervision of these electric power systems.

The overall aim of the control and supervision systems is that the power system is utilised in an economically optimum way and that operation safety goals are fulfilled. The power system may be in a number of different states depending on outer circumstances, for instance caused by disturbances, such as production and line tripping. When the power system is in the normal operational state, the economical optimisation of the operation constitutes the main task, while aspects regarding delivery security has to become prioritised at alert or emergency operation.

All over the world, there is a de-regulation of the electric markets. Important questions for the reliability in the electric power systems of the future are the origin of new actors and the reduced organisational connection between production and transmission resources. An additional area that draws more and more attention among the power companies is questions around risk handling. On a de-regulated electric market, there are also difficulties to offer spare capacity, since normally unutilised capacity often costs large amounts to maintain in operationally safe condition. A natural consequence of the development in progress, including the de-regulation of electric markets, is an increased focusing on network operation and operational problems. The need for updated information increases with that different operators have to co-operate with each other in order to get a total electric power system to operate satisfactorily. Since it is not always obvious that all relevant information is available for all parties in an electric power system, new demands are put on the exchange of the information that is available. With the sharpened competition between different actors even higher demands are put to being able to utilise existing establishments in an optimum way.

SCADA (Supervisory Control And Data Acquisition) functions constitute the basic part in the operation management system. SCADA comprises data collection, supervision, control and presentation of different functions in the electric power system. SCADA is closely connected to the calculation functions that are parts of EMS (Energy Management System) and DMS (Distribution Management System). EMS comprises analysis and optimisation of the production and transmission systems via functions for production planning, production control and power system analysis, while DMS constitutes corresponding functions for distribution network applications.

An additional interesting area is DSM (Demand-Side Management), which comprises energy measuring and load control, among other things with the aim to influence load profiles and to reduce load peaks. A relatively new area is business systems, concerning energy trade and customer service, so-called BMS (Business Management System).

The technical base for the hardware that is included in the SCADA and EMS systems can be divided into three part systems: local systems, communication systems and operational centre systems.

It is the local systems that handle data collection via remote terminals, so-called Remote Terminal Units (RTUs), and ordering of different measures, such as for instance connection operations in the network. Thus, these systems constitute the interface to the processes in the electric power system. Since the electric power networks constitute geographically very widespread processes, good communication channels are required between the different units that are included in the control and supervision systems. Operation centre systems may be said to constitute the actual brain in the systems for control and supervision of electric power networks, which leads to that the activity at different operational centres has to be co-ordinated in that the computers of the operational centres communicate and co-operate in hierarchically formed structures. The hierarchic demand is a natural result of the operational organisation of the power companies and the geographically spread-out process.

The main tasks for SCADA can be divided into data collection, supervision, control, accounting, planning and follow-up. In the part function of the SCADA system that handles supervision, the treatment of measurement values and indications, the supervision of limit values and indications and event and alarm handling are included. Operational limits are supervised and passing of an operational limit result in an alarm in the operational centre. Different methods are used in order to indicate alarms and fault signals, depending on their nature and significance for the operation of the electric power network.

The part function of controlling comprises manoeuvring, set point control, blocking and sending of control orders and limit values to local regulation equipment. The nominal limits concern in most cases pure electrical quantities, such as voltages, currents, powers and phase conditions, and are typically set after recommendations from the manufacturer of the units, based on the present design. These

recommendations are based on tests of the apparatuses and/or theoretical calculations of its properties, and margins that should assure a safe operation also at somewhat different operational conditions. By help of different calculation functions, measurement values that has not been fetched directly from the system can still be calculated more or less reliably with help of measurement values from the network by applying theoretical models for the processes.

The basic functions that are included in EMS are constituted by the functions for production planning, production control, topology determination, state estimation, network calculation functions, safety analysis and possible practising simulators. In order to carry out network calculations, a good model of the electric power system is required, which is achieved via the functions for topology determination and state estimation. The module for topology determination builds up an electrical model that describes how the nodes and components of the electric power network are electrically connected to each other. All measurement values suffer from larger or smaller errors, and certain measurement values are missing due to faults in equipment or lack of remote terminals for data collection.

The fast development of power semiconductors creates new possibilities to control and supervise electric power systems. An increased introduction of power electronics, for instance in the form of so-called FACTS components (Flexible AC Transmission System) can contribute to change the electric power systems from being substantially passive electrical networks for transmission of electric energy to actively controllable systems, in which power flows can be influenced by automatics or by measures initiated by operators in management centres.

Sekiguchi and Masui have in the European patent application EP 0 853 367 with the title "Electric Power Control System" described a system for remote supervision and regulation, including protection functions in the form of relay protections, of an electric power network. The described embodiment comprises besides collection means for measurement values also processing and memory units, which are connected by a communication network. Data in the described system is handled in digital form and the regulation system for information collection contains a main area

(so-called core-area) and a communication area (so-called web-area), and program modules with possibilities to communication in order to control the relay protections. Data and status concerning different relay protections can be graphically shown at a screen, and new programs can be downloaded into the relay protections via the user interface and a communication network.

In a related patent application EP 0 940 901, "Control system, method of protectively controlling electric power system and storage medium storing program code", Shirota et al. have developed the earlier described system for remote supervision and regulation to also include an accurate time marking of collected measurement data and a method for obtaining parameters for transmission lines. Collected measurement data can be time marked and are sorted by means of an accurate time label received from a GPS satellite. The current parameters for impedance values of a transmission line can be obtained based on collected data regarding voltages and currents in the transmission line.

The two patent applications describe in the first place a method to connect and co-ordinate protection and control equipment in an electric power network. The control units for protection devices and processing units, which are connected via a communication network, constitute important parts. The described procedure is based on the use of conventionally available and thereby often utilised information in the operational data network.

In the European patent EP 0 125 796 with the title "System and protection apparatus for monitoring and control of a bulk electric power delivery system", a device is described, which is designed for to be placed at an electric transmission line and for measurement of parameters associated with a power flow over the line. The device contains besides sensors, which for instance can measure temperature, current and voltage, also a radio transmitter for communication with a receiver. The device can be placed at a transmission line without having to make this voltage free. Data collected via the device on the transmission line is transmitted via radio to the receiver placed at earth potential, for instance in the lower part of the power-line pylon. The patent describes further a method for supervision of the power flow at a

number of transmission lines in a switching station by using a number of the above described devices placed at different transmission lines in the station. The receiving station at the ground can beside receiver and antenna also include a processing unit, a memory and a communication device for sending collected, and possibly processed, measurement data on to other units in the electric power system.

The described device measures only parameters directly available on or at an electrical conductor surrounded by air. The measurements are performed on a passive component in the electric power network, a line, without intending to measure on an in advance determined critical point, so-called "hot spot". The system contains a one-way information flow from the receiving station of the measurement device to a supervision unit and is utilised as a pure overload protection. The receiving station can control several lines in the same way in the same time, by measurements of identical type. Examples on control of the power flow can be by reconnections in the network or changes of the tap-changer position for transformers with on-load tap-changers. The control of the power flow through supervised transmission lines is based on data collected locally within the switching station.

In the European patents EP 0 233 507 with the title "Transmission line sensor apparatus", and EP 0 231 909 with the title "RF-antenna for transmission line sensor", devices for information collection from high voltage conductors surrounded by air and their use according to above patents are described more in detail.

A general problem with supervision of electric power networks according to prior art is that the measurement data that is used does not have any close and safe connection to the actually critical points in the electric power processes in an electric power network. Control is today to a large extent performed by means of limits based on more or less static models and calculations of differing accuracy.

SUMMARY

A problem with supervision systems according to prior art is that the control of and/or limits for controllable parameters are dependent on calculations and/or models of

differing accuracy and reliability. This in turn leads to that, in order to get a safe operation, one has to apply relatively large security margins in the operation of electric power objects and electric power plants, whereby the utilisation does not become absolutely optimum. Another problem with supervision systems according to prior art is that measurements from different types of electric power object rarely are used together to utilise the margins in each electric power object.

A general object with the present invention is thus to provide a supervision method and devices therefore, to utilise already existent resources in electric power plants and electric power networks more efficiently. A further object with the present invention is to provide a method and devices that with time enables building-up an experience that further can improve the understanding of complex electric power systems and the operation thereof. Another object is to provide methods and devices to be able, in an earlier stage and/or with higher security, to detect operational disturbances in an electric power system. A further object is to optimise the operation of the electric power system to minimise the impact on the environment that electric power systems have.

These and further object are achieved by methods and devices according to the enclosed claims. In general terms, the present invention can be said to utilise direct measurement of marginal critical quantities in direct connection to interesting point in electric power processes in the different electric power objects. These points are generally located at places difficult to access, such as at high potential in limited spaces, at high potential inside encapsulations with solid or liquid insulation, or at rotating parts. The marginal critical quantities have thereby to be measured at these places difficult to access. The measurements give direct information about actual, now valid operational margins concerning marginal critical quantities and in particular quantities that are both marginal critical and material critical. Information about available margins is transferred to other units within the network or the plant. The electric power plant or electric power network can then be controlled emanating from such actual operational margins from several different units in the plant, which enables a more efficient operation of the electric power plant or the electric power network, and can give decision support for extension of networks by identifying

bottlenecks. By the direct measurement, a fast feedback is achieved if accomplished operational changes do not bring about intended result. The measurements give furthermore new paths for detecting faults in the systems. Furthermore, databases of operational conditions can be built, which then can be used both as support of the operation of the system and for future maintenance, model designing etc.

The advantages with this is that one can, without renouncing security, utilise already existing margins in electric power systems. Overdimensioning and losses can be minimised, which also has advantages concerning the environment.

With the deregulation of electric markets, there is a growing interest in utilising the network and its included components harder and harder, which sometimes is expressed as a request to "drive" the electric power networks and its included components closer and closer to their physical limitations. There is thus today an economical request to better utilise available transmission capacity in electric power networks as well as margins in components. This leads to a need for to better being able to determine the present margins to stability limits for the electric power network and bring information about the actual and present condition for component, such as for instance the temperature in the windings of an electrical machine.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention and further objectives and advantages that are achieved thereby are best understood by reference to the description below and the enclosed drawings, in which:

Fig. 1 is an embodiment of an electric power plant according to the present invention;

Fig. 2 is an embodiment of an electric power network according to the present invention;

Fig. 3 is an embodiment of an electric power network according to the present invention with different types of electric power units;

Fig. 4 is an embodiment of an electric power network in several levels according to the present invention;

Fig.5a and 5b are schematic drawings and diagram showing how temperature margins in electric power objects can be utilised by the present invention;

Fig.6a to 6d are schematic diagrams showing how time variations in the utilisation of electric power objects can be utilised by the present invention;

Fig. 7a to 7e are schematic drawings and diagrams showing how operational margins in electric power plants can vary and be utilised by the present invention;

Fig. 8a to 8e are schematic drawings and diagrams showing how operational margins in electric power objects can vary and be utilised in electric power plants by the present invention;

Fig. 9 illustrates a communication network and associated information flows according to the present invention;

Fig. 10 shows a flow diagram for a method according to a first aspect of the present invention; and

Fig. 11 illustrates an electric power network presenting a so-called bottleneck.

DETAILED DESCRIPTION

In the following detailed description, a number of concepts will be used. In order to avoid interpretations of these notions, which differs from what is intended in the present description, a number of these concepts will first be defined, before the actual description starts.

An <u>electric power object</u> is a device in an electric power system, which comprises a process or a course of events of electric/electromagnetic type. The electric power object is most often controllable, either internally or by external switching devices, and has via its controllability an influence on electrical parameters in the electric power system, in which the object is present. The group of electric power objects comprises e.g.: electrical machines (motors and generators), transformers, reactors, capacitors and power electronics.

An <u>electric power plant</u> is defined in the present description as a group of interconnected electric power objects, which are located within a relatively limited area and are operated in a co-ordinated manner and which preferably belong to the

same operator. The operation of the electric power plant can be influenced by the inherent behaviour of the objects as well as an active control by a supervision unit.

By electric power network is in the present description intended a group of electric power plants and single electric power objects, if any, interconnected by electrical lines, typically distributed over a somewhat wider geographical area than an electric power plant. The operation of the included components are supervised and controlled in a co-ordinated manner, possible also in co-operation with superior, side-existing and/or subordinated electric power networks, by a supervision unit. An electric power network can e.g. be included as a part in a superior electric power network.

Electric power unit is used in the following as a composed concept for electric power object, electric power plant and electric power network.

The concept electric power system is used in the wide sense of a general system of different electric power units.

In different electric power objects in electric power systems, many of the critical and most interesting electric/electromagnetic courses of events takes place at "places difficult to access". Parameters concerning these electric/electromagnetic courses of events are therefore normally difficult to obtain. In prior art, one has chosen to meet the insecurity concerning critical parameters with certain drawn-up safety margins and limits, based mainly on models and calculations. The present invention is based on measurements, which give earlier not utilised information. By "places difficult to access" is in this description intended:

at rotating part,

at high potential in limited spaces, and/or

at high potential within encapsulation with solid or liquid insulation.

Rotating parts are commonly present in electric power objects, mainly in rotating electrical machines. To measure parameters directly at such parts has earlier not been considered to be applicable in practice. Measurements at high electrical potential, e.g. over 1 kV, or very close to such a high electrical potential, have also to

a large extent been avoided earlier. High voltages are present in many electric power objects and space limitations is a common reason to why one does not perform measurements close to these. Encapsulations are often used to screen high potentials and constitute also sometimes an obstacle for a simple supervision of different parameters, in particular in cases where solid or liquid insulation is present. Common for these places difficult to access is that measurements at these places demand relatively complex arrangements. In prior art one has therefore in general chosen to relinquish the use of such quantities, and instead chosen to trust models and calculations or limit values. In certain cases, one has measured certain quantities during testing procedures or similar in order to characterise the electric power objects, but has earlier not really realised the benefit of continuous measurements during operation. This is mainly based on the difficulties to perform relevant measurements.

The parameters that are of interest are parameters that have a direct or indirect connection to the operational state of the electric power objects. The parameters are of very differing character. Some of the parameters can be denoted as marginal critical quantities and some of the parameters can be denoted as material critical quantities, and some can be denoted as both margin and material critical quantities.

By "marginal critical quantities" is intended quantities that are associated with some kind of limit. If this limit is exceeded, it will have a direct influence on the operation of the electric power object, relatively independent of other quantities. Thus, for these, direct limits can be set-up. If the limit is exceeded, a well-defined damage or influence on the operation is achieved more or less directly. Examples of marginal critical quantities are: temperature, load angle, phase angle, slip, current, voltage, frequency and torque. In current and voltage are also phase quantities associated thereby included. A too high temperature can over a certain limit cause a direct material damage. A phase angle in a synchronous machine has for instance an absolute limit, when the stability of the synchronous machine ceases. Practical limits for such quantities have of course to be set with a certain margin. Voltage can be denoted as a marginal critical quantity, since it has a limit associated with a

maximum transmission capacity. If one falls below this limit, the voltage stability in the network is lost.

By "material critical quantities" are intended quantities, which in principle also have a limit. This limit can be difficult to determine, since it is dependent of so many surrounding parameters. These limits do often not constitute any really critical limits but can normally at least during a shorter period of time be exceeded without for sure causing a damage or operational disturbance. At longer exceedings are normally a gradually degradation of the material obtained, a shortening of life. Examples of material critical quantities are: temperature, current, partial discharges (PD), vibrations, overtones, minus sequence, zero sequence, rotational speed, air-gap flux and speed. These quantities have often rated values or nominal values for a certain electric power object. It is, however, mostly possible to exceed these nominal values, at least for a shorter time, without causing any immediate damages on the electric power object. A current through a winding in a transformer that exceeds the rated current does not always case a damage. If the winding is cold from the beginning, either as a result of that the transformer earlier has been utilised sparsely, or because of that the temperature of the surroundings is very low, the transformer can withstand a temporary overcurrent without being damaged. If on the contrary the overcurrent is present for a certain time, the winding is probably heated up by time and can at a later occasion reach temperatures that are harmful for the material. The material critical quantities are often related to limits for the marginal critical quantities by more or less complex models and relations. Existing static limits for material critical quantities are normally set with certain, mostly relative large, safety margins.

Vibrations constitute a rather typical material critical quantity, for which it is difficult to define any type of exact limit, but instead it has a degrading effect on the material with time. If vibrations are on during a time period, damages will eventually arise, if the level is sufficiently high, i.e. over a limit. It is not the level itself, but more a combination of level and time that gives rise to problems and damages in the case of material critical quantities.

A quantity such as temperature can according to the reasoning above be characterised as both marginal critical and material critical. There are values for e.g. polymers, which can not be exceeded without having the material going through a non-reversible process. At the same time, a gradual degradation of the material, i.e. an ageing phenomenon, can occur if the temperature is over another lower level, and the consequence depends in this context both on the time and the level itself. Current can also be placed in this double assignment, as a result of its close connection to the temperature.

Of all these parameters, the temperature is the incomparably most important, since all electric power objects have some sort of temperature dependent margins.

In Fig. 1 a typical example of an electric power plant 1 is illustrated. Two electrical machines 10, which in this case are similar, operate as generators, each of which produces a certain electrical power. The electrical machine 10 comprises a rotating part 17 and a stationary part 19, normally denoted as rotor and stator, respectively. At the rotor, there is a sensor device 18 arranged, which measures the temperature of the rotor winding, the rotor current, the vibrations of the rotor and the shaft torque. The sensor device 18 sends measurement data concerning these parameters to a machine control unit 20 via a transfer channel 21, preferably wireless, e.g. via radio waves. The machine control unit 20 is also responsible for the normal operation and the control of the electrical machine 10.

The electrical machines are via connection lines 36 connected to a power electronics unit 12 for e.g. voltage regulation, reactive power control or charging of batteries. The power electronics unit 12 can have one or several terminals and can be connected in series as well as in shunt to the power network. The power electronics unit 12 is provided with a temperature sensor 22, which measure the temperature at certain critical high voltage parts in the unit. Temperature data is transferred to a control unit 24 for power electronics, which otherwise is arranged to control the operation of the power electronics unit 12. The transfer is in this example performed via an IR link or fibre optics 23.

Both the power electronics units are furthermore connected to the primary side of a transformer 14 via connection lines 36. A sensor device 26 is arranged in direct connection to the high voltage parts and measures temperatures and current (including phase quantities) on the windings. These measurement values may for instance be transmitted via a combination of radio wave connections and fibre optical communication links 27 to a transformer control unit 28. The secondary winding of the transformer is then connected to an external electric power network via an external plant line 16.

The sensor devices 18, 22, 26 are arranged in order to measure marginal critical parameters at places difficult to access. Besides these measurements, also other quantities can be measured at these places, such as material related quantities, e.g. the vibration measurements at the rotors 17. Furthermore, the control devices 20, 24, 28 can obtain results of measurements of parameters from other more conventional places, e.g. stator temperatures or currents and voltages at relatively low potential.

The machine control unit 20 processes the measurement data obtained from the sensor device 18. Emanating from this processed data, the machine control unit 20 can control the unit according to predefined action plans. These action plans may e.g. comprise protection and defence functions. The machine control unit 20 extracts also certain information from achieved measurement data, summarises the information in a suitable manner and sends the information further over an information link 30 to a plant supervision unit 32.

In a similar way, the control units for power electronics 24 control the power electronics units 12 based on the temperature data that has been received from the temperature sensor 22. In this example, the control units 24 for power electronics can either, without processing, forward the unprocessed data directly via an information link 30 to the plant supervision unit 32, or directly in the control unit 24 process collected measurement data. If for instance the information link 30 to the plant supervision unit 32 does not work, it is preferable to be able to directly in the control units 24 process measurement data and compare with set-up levels or levels stored in databases in order to take emergency measures, such as bypass switching

or disconnection of the power electronics in the unit when needed, if temperature limits are exceeded. In order to achieve a co-ordinated control of the electric power plant, measurement data concerning the actual temperature on the power semiconductor from the temperature sensor 22 can, however, in the normal case be sent directly forward to the plant supervision unit 32, where possible decisions about actions can be co-ordinated with other information before decision about measures is taken.

The transformer control unit 28 processes, in a similar way as in the machine control unit, the measurement data that is received from the sensor device 26. Emanating from this processed data, the transformer control unit 28 can control the transformer according to predefined action plans. These action plans may e.g. comprise protection and defence functions. The transformer control unit 28 extracts also certain information from achieved measurement data, summarises the information in a suitable manner and sends the information further over an information link 30 to a plant supervision unit 32.

The plant supervision unit 32 receives information from the control units 20, 24, 28 of the different electric power objects. In certain cases, the information is processed and adapted, in order to reduce the amount of data that is transmitted, such as the case is e.g. in this example for the machine control units 20 and the transformer control unit 28. In other cases, such as e.g. for the power electronics, the information to the plant supervision unit 32 comprises more or less raw data from the temperature sensor. The plant supervision unit 32 collects the information from the control units 20, 24, 28 and processes this information in order to estimate the present operational margins for the different electric power objects 10, 12, 14. This estimation is performed currently, either continuously or intermittently. The present operational margin for each electric power object 10, 12, 14 is therefore currently updated and can in each moment give a picture of the state of the object and which margins there are to utilise. The plant supervision unit 32 can, emanating from these present operational margins, control the different parts of the electric power plant 1 in an optimum way. Also certain external information can be used. Control information is then sent back to the control units 20, 24, 28 for the different electric power

objects, so that the operation of each object 10, 12, 14 is changed according to the overall plan prepared by the plant supervision unit 32. The plant supervision unit 32 is preferably also provided with a communication link 34 to external units, via which external control signals can be received.

In the sketched example, all included electric power objects comprise measurement sensors. One may of course also apply the present invention on plants, where only certain electric power objects comprise measurement sensors at places difficult to access. However, it is then also preferable if also electric power objects that do not themselves have a supervision of marginal critical quantities to be controlled based on information from the electric power objects that have such measurements. In other words, if e.g. the power electronics 12 should not be temperature supervised, one should in any case want to control these based on the information received from the electrical machines 10 and the transformer 14. The marginal critical quantities are thus utilised to control and regulate the overall operation of the entire electric power plant 1. The large advantages of using precisely present operational margins based on marginal critical quantities measured at places difficult to access will be discussed in more detail below. At least two of the electric power objects are provided with sensors for measurements of marginal critical parameters at places difficult to access, which gives co-ordination advantages, which are discussed in more detail below.

The same basic principle that permeates the operation of the electric power plant in Fig. 1 can be brought to a more overall level. Fig. 2 illustrates an electric power network 2 comprising three electric power plants 1. Each electric power plant 1 comprises a plant supervision unit 32. The electric power plants 1 within an electric power network 2 are connected to each other either directly by plant lines 16 or by an electric power object 40 and plant lines 16, which electric power object 40 in turn can be connected to other electric power networks by a network line 52. The electric power object 40 comprises an object control unit 44, which is arranged for information transmission to and from a network supervision unit 46. The network supervision unit 46 is also connected to the plant supervision units 32 of the electric

power plants 1 for transmission of information. The network supervision unit 46 is furthermore preferably provided with a communication link 54 to external units.

Each electric power plant 1 has an inner structure, similar to the one described in connection with Fig. 1. This inner structure is, for the sake of clarity, only shown for one of the electric power plants. The electric power plant 1 comprises in the illustrated example three electric power objects 40 comprising one object control unit 44 each. The electric power objects 40 are electrically connected to each other by connection lines 36 and outwards through a plant line 16. The electric power objects 40 comprise preferably also sensors 42 for measurement of marginal critical quantities at places difficult to access, which communicates with the object control units 44. The object control units 44 forward the information associated with the measured parameters to the plant supervision unit 32.

The information that is transmitted from the plant supervision units 32 to the network supervision unit 46 is based, at least to a part, on the measured marginal critical parameters. The information may consist of operational margins for the plant 1, other operational information as well as other information. The operational margins can also be gives together with other information, e.g. price information, conditions for the validity of the operational margins etc. The information can thus also include certain external parameters that can be used as external control signals. Other operational information may e.g. consist of reporting of abnormal operational conditions, which e.g. may indicate a closely imminent fault. Normally, no direct information about e.g. measurement values are transmitted to the network supervision unit 46, but the plant supervision unit 32 together with respective control unit 44 constitutes an information filter, where unnecessarily detailed information is processed to useful information before it is brought further. The network supervision unit 46 can, emanating from the operational information that is received from the plant supervision units 32, control the operation of the electric power network 2 in an optimum manner. It should also be noted here that the information about operational margins etc. that is used for the network operation is operational margins based on the critical margins that presently has been measured. This means that the decision basis that is offered to the network supervision unit 46 is currently updated, which is

why the prerequisites for the operation of the electric power network are changed with time.

In the above examples, the plant and network, respectively, has been built by homogeneous pieces. In Fig. 3, an electric power network 2 is instead illustrated, which comprises three electric power units. These electric power units are in this example an electric power object 40, an electric power plant 1 and a subordinated electric power network 2' interconnected by a plant line 36 and a subordinated plant line 16'. The electric power object 40 has a control unit 44 with access to operational margin information concerning the electric power object 40, which control unit 44 communicates with the network supervision unit 46 via a link 30. The electric power plant 1 has a plant supervision unit 32 with access to operational margin information concerning the electric power plant 1, which plant supervision unit 32 communicates with the network supervision unit 46 via a link 34. The subordinated electric power network 2' has a subordinated network supervision unit 46' with access to operational margin information concerning the electric power network 2', which subordinated network supervision unit 46' communicates with the network supervision unit 46 via a communication link 54'. This illustrates that all electric power units in an electric power network do not have to be electric power units from the same level in a hierarchical structure.

Fig. 4 shows one more example of how a hierarchical electric power network structure can be formed. An electric power network 2 comprises in this example three primary subordinated electric power networks 2', with associated network supervision units 46'. These primary subordinated electric power networks 2' comprise in turn secondary subordinated electric power networks 2", with associated network supervision units 46". In this manner, an hierarchical structure can be formed, at the same time as cross connections between different electric power units can give rise to masked systems. Information exchange can also be performed directly between different electric power units, as illustrated by the information links 56, besides the electrical connections. In a typical case, distribution networks are from an hierarchically point of view with respect to its electrical connection formed in

a radial manner, while transmission networks mostly have a masked electrical formation.

An electric power network with this organisation is possible to apply in all different parts of an electric power system. Generation (production) and use (load) of electric power are obvious application areas for these networks. However, also transmission and distribution networks are interesting for this type of control.

In most electric power objects, a large part of the interesting processes takes place at places, which are not so available. These places are often properly enclosed, have lack of space around, are moving, are at high potential or are sunk into inhospitable chemicals. This implies that it has been relatively complicated to supervise the interesting processes in detail. One has possibly made tests during the construction or installation phases in order then to abandon direct measurements at such places. Instead, one has relied on calculations according to created models, or on static limits set after measurements or models.

Most electric power objects today have different types of rated values, nominal values or limits associated with its operation. Often, these values concern the electric properties such as current, voltage, power etc., since these are of primary interest for a user. They are furthermore often given for places that one can measure these at, i.e. places easy to access. As mentioned earlier, these parameters are connected to the marginal critical parameters that appear on places difficult to access in the electric power system by more or less complex relations. These relations also have a tendency to become more and more complex the longer from the central processes one gets, i.e. the longer from the places difficult to access one is moving.

If one, as is done in devices according to prior art, control ones electric power objects and electric power plants according to these static limits, the plants are often operated with a sometimes unnecessarily ample marginal. By instead placing sensors closer to the actual process, i.e. at places difficult to access, and furthermore rather also measure quantities that are directly connected to the margins, a more dynamic control can be achieved. Marginal critical as well as

material critical quantities contribute to give a good estimation of the conditions at the actual process. From these, one may estimate operational margins by e.g. calculating dynamic limits for other marginal critical and/or material critical quantities. Such a dynamic control can then be spread further within the electric power network and there also allow a new type of dynamic control.

In order to illustrate the possibilities that arise, some simplified examples are now described. In Fig. 5a, an electric power object in the form of a transformer 60 is schematically illustrated. According to calculations, the transformer manages to transmit a maximum power P_C. This critical power P_C is calculated emanating from constructional considerations concerning the insulation material around the windings and e.g. the temperature of the surroundings. It is stated to withstand a temperature of T_C, over which the material is damaged. In order to be able to handle smaller erroneous measurements and fluctuations, a nominal power P_N for the transformer is set, which corresponds to a nominal temperature T_N for the winding (at continuous operation).

In Fig. 5b, a transformer 60' of a type that can be included in an electric power plant according to the present invention is illustrated. The transformer 60' is provided with a temperature sensor 62, which is connected to a control unit 64, which in turn is in communication 68 with e.g. a plant supervision unit (not shown). In this example, it is now assumed that the transformer 60' is exposed for a lower surrounding temperature than expected, or that a cooling air-flow 66 exposes the transformer for a cooling that is larger than the one the calculations of the critical power P_C is based on. This cooling results in that if the transformer 60' is used at the nominal power P_N, the temperature in the winding will only amount to $T_{N'}$. As a result of the unpredicted cooling, there is thus an unutilised margin in the transformer 60'. In the control of a conventional electric power system, such margins can not be detected, but the control of the operation is still performed based on the static original model. In the transformer 60' used in the present invention, the temperature is measured continuously. If the transformer is operated at the power P_C, a temperature $T_{N'}$ will be measured. The control unit 64 may then simply note that there is a temperature margin to utilise. This fact is reported further through the communication link 68 to

the supervision unit of the plant. The supervision unit can then, if it is suitable or required, increase the power that is sent through the transformer 60' to a value P_0, which exceeds the nominal power P_N. When equilibrium is established, the temperature in the winding will have increased to T_0, which lies with a sufficient margin below the critical temperature. This power flow can thus be held continuously, as long as the enhanced cooling is present. If the enhanced cooling disappears, the temperature in the windings will rise and come closer to the critical limit, and the power through the transformer has to be limited.

Further advantages with systems according to the present invention arises at non-static operation of the electric power units. In Fig. 6a, the generated power from an alternating current generator during constant operation is shown. According to construction considerations, a nominal power of P_N has been stated, which at continuous operation should correspond to a certain critical temperature in the rotor winding T_C. In Fig. 6b, the rotor temperature is shown, during the corresponding time period. If the machine now only is required to be in operation during limited time periods, there will be no temperature equilibrium established in the rotor. In a generator according to prior art, P_N can still not be exceeded without releasing different overloading protections. In a system according to the present invention, other control courses may be used. In figure 6c an operational course is shown, where the generator is operated in order to generate a power P_0, exceeding the nominal one during limited time intervals. In figure 6d, a corresponding diagram over the temperature course in the rotor is shown. By supervising the rotor temperature, one can thus during shorter periods allow such power extraction that during continuous operation should cause material damages on the plant.

These examples above have been directed to the operation of single electric power objects. Corresponding reasoning can, however, be transferred also to the control of electric power plants and electric power networks. In order to achieve in these cases an optimum operation, also other side conditions, which in this context can be considered as "external data", should be included in the control of plants and networks. These side conditions can be constituted by other technical, economical, environmental as well as administrative data. Control of an electric power network

can for instance be used for planning transmission capacities and for example avoiding that lack of capacity is created in certain transmission corridors and thereby so-called bottlenecks in the electric power network. There is thus a natural inherent connection, but also an inherent contradiction, between operational safety, electric quality and economy.

An efficient operation of electric power objects and electric power plants can be achieved by utilising the possibilities to measurement of marginal critical quantities at places difficult to access in an electric power system. A well thought-out use of such measurement data can result in reduced loads and improved life times for electric power objects. This can for instance be accomplished by an efficient utilisation of margins existing in the object or by a redistribution of power in plants or networks. A balanced planning between operational safety and operational economy should also include environmental aspects. Today, optimisation algorithms are used at the operation of an electric power system mainly in order to minimise costs, or losses in the network. Optimisation algorithms can also be used in order to make balances between operation safety aspects and economical considerations, and also environmental considerations can be included in this balance. As example of a balance between operational economy and environment where certain production units are run without considerations taken to their margin costs, for instance with the object to reduce outlet of greenhouse gases. This type of balances between different priorities can result in an increased utilisation of certain electric power objects, which thereby are more interesting to supervise and control, and at need and under controlled circumstances being able to overload during limited times. Furthermore, it can for instance be of interest letting operational safety aspects get a higher priority and precede when there is a risk (increased probability) for a disturbance in the production or transmission system that can lead to an extensive system break-down, i.e. a collapse situation.

In Fig. 7a, an electric power network 2 is illustrated, comprising three electric power plants 1, in the figure denoted by A, B and C, each one of which having a plant supervision unit 32. In this example, the electric power network 2 further comprises an electric power object 40 and a network supervision unit 46.

Fig. 7b illustrates extracted power (broken columns) and power margin (unfilled columns), respectively, for the plants included in the electric power network at a first moment. One can here notice that extracted power from plant B is very close to maximum available power. The plant C has in contrary a good margin. At a possible lack of power in the network, one may therefore advantageously utilise plant C to remedy this.

Fig. 7b illustrates the same quantities in the same network, but at another moment. The conditions have now changed. The plant B has now announced that its margin has been increased considerably, e.g. due to that additional electric power objects now have been introduced. At the same time, the plant C has been affected by operational difficulties in that the surrounding temperature has been strongly raised. The available power margin has therefore decreased considerably. The planning of the measures at an operational disturbance in the entire electric power network should now be changed, so that an efficient utilisation of the margins can be made.

If one furthermore considers the time aspect for operation control, the conditions can be changed further. From Figs. 7b and 7c, it might appear as if plant A is the most stable one and very probable has the highest potential for helping managing operational disturbances. In Fig. 7d available power a short limited time period is, however, illustrated. It here shows that the plant B has a large inertia concerning heating-up at overpower extraction, and thus during a short time can deliver a very large power. The same reasoning is valid also for plant B. Plant A is in contrary very sensitive to overpower extraction and can only increase its available power very marginally, even for shorter periods of time.

In Fig. 7e, another important factor - the price - is further illustrated. The decisions about how the electric power network shall be controlled depend in a part on the pure technical reasoning. However, also the price for the available powers will have a conclusive importance. In certain cases, one may even choose to intentionally shorten the life of a plant by e.g. operating the plant in an unfavourable way, if only the economical compensation is sufficiently high. Operational margins and

information about these can thus be provided also with information completely originating from the outside, e.g. price or certain environmental considerations. This external information is added to the electric power system from external sources in an intentional way in order to support different decision processes.

Figure 11 shows an example of an electric power network with two input points H, J and one load area L, to which there are two main paths for the power to flow. In an electric power network, so-called bottlenecks K can appear at the transmission side in that electric power objects have different load capability. In the example, the electric power object K is assumed to have a lower load capability and thereby constitute a bottleneck limiting the transmission capacity between the input points (production areas) and the load. As a result of that the power flow is changed at different load and production distributions, different electric power objects can constitute bottlenecks at different moments. By for instance measuring the temperature at critical places in different electric power object, often at places difficult to access, their present transmission capability can be determined. This improves the possibilities to supervise and utilise available capacity in different electric power objects, which can improve the transmission capacity and operational safety and reduce the losses in the electric power network. Knowledge about the present capacity creates improved possibilities to overload components, for instance transformers in important nodes, which can be used for dynamic supervision of marginal critical quantities. Possibilities to actively influence, control, the power flow creates an enhanced flexibility concerning power flow control and opens hereby up new possibilities for optimising the operation of the electric power system.

A closely related example concerning optimum capacity utilisation is illustrated by Fig. 8a. In the figure, an electric power plant 1 is shown, with four electric power objects 40, denoted D, E, F and G. The electric power object D can be connected to external units either through electric power object E or G. In the same way, electric power object F can be connected to external units either through electric power object E or G. In Fig. 8b, an operational situation for the plant is shown. Electric power object D produces a power that corresponds to the broken column. This power is brought through electric power object E. The empty columns illustrate as

earlier presently available power utilisation. Electric power object F also produces a power, which is brought through electric power object G out to an external network.

In Fig. 8c, the plant is shown at a later occasion. Available power transmission through electric power object E has by some reason been reduced, but is enough for the power produced by F. In the same way, the power from D can be transmitted by utilising the capacity of G by its maximum. A reconnection can in this way protect the total power generation of the plant.

In Fig. 8d, one has tried to optimise the total power generation. By utilising the margins for D and G by its maximum, a smaller increase can be achieved. Fig. 8e shows the situation at a later occasion, where the margins for electric power object F has increased. Now, it is instead advantageous to let the power of F pass E and instead reduce the power of D to the maximum level of G, in order, in a total view, to have a larger power from the plant.

The simple examples above show the advantages one may achieve by a dynamic margin supervision. In real systems, all relations become of course much more complex, but the basic principles with that an increased dynamic supervision of directly marginal critical quantities opens up for a new type of supervision and control philosophy are anyway valid. Knowledge about the present capacity of different electric power objects can be used for a dynamic supervision of marginal critical quantities. Possibilities to actively influence, control, the power flow hereby opens up new possibilities to create a flexible electric power system.

With the above systems, one may work at three time horizons. The immediate is of course to work with the direct operation. Available margins can be used directly in order to accomplish an optimum control of the systems. In another aspect, the measurements can also be used for operational planning of e.g. programs of measures to be taken at fault situations or temporary load peaks etc. As a third time aspect, the measurements can also be used for prognosing purposes, which can be used for long term production or network expansion planning.

The measurements of marginal critical quantities at places difficult to access constitute as described above the basis of the new way to supervise electric power systems. However, also other types of measurements are in a certain degree necessary in order to refine the decision foundation. Such measurements can e.g. be conventional measurements at places easy to access, or measurements of e.g. material related quantities, topology, position, velocity etc. These measurements can refine the decision foundation that is the basis for the control.

From the above examples, one may realise that marginal critical quantities from places difficult to access in one electric power object with advantage are used in combination with marginal critical quantities from places difficult to access in another electric power object. The combination of this type of information opens up new possibilities for control methods, in particular when the different electric power objects are of different categories. The combined information can then easily be communicated back to the individual object as control information, whereupon the control of the object can be performed locally, i.e. in direct connection to the place where the original measurement was made.

Depending on which type of electric power object the measurement and control concerns, the marginal critical quantities and the places difficult to access are of different character.

Electrical machines comprise motors and generators of different types. Most of the machines are rotating electrical machines comprising rotor, stator and windings belonging thereto. The electromagnetic process in an electrical rotating machine takes in principle place in the gap between the rotating and the stationary parts. Since the conditions in the rotor are more isolated and difficult to estimate, the rotor margins constitute normally the most critical ones in a rotating electrical machine. Quantities measured directly at the rotor, such as current, voltage, phase quantities, temperatures, constitute therefore the most interesting quantities. Also quantities such as shaft torque and partial discharges (PD) can be of interest. Additional quantities that can be of interest to measure are e.g. the mechanical vibrations in the rotor. A changed appearance of the vibration spectrum may indicate incipient

mechanical problems, and may also bring about changed operational control, in order to avoid unsuitable breakdowns.

The limits for how hard a rotating electrical machine can be utilised is often set by considerations regarding temperature, e.g. the temperatures of the stator and field windings. For instance a synchronous machine, which comprises a current converter device and a rotor provided with windings, can be provided with a co-rotating processing unit, and a likewise co-rotating communication unit for wireless information transmission to a stationary unit. The transmission can appropriately be performed via radio. To the rotor is also at least one co-rotating sensor for measurement of marginal and/or material critical quantities associated with the rotor, for example temperature. A stationary processing unit is connected to a stationary communication means. The stationary communication means is arranged to send and receive data by the wireless information transfer with the co-rotating communication means.

By placing a processing unit co-rotating with the rotor, one achieves a possibility to local treatment of locally achieved data. Thereby, the amount of data that has to be transferred between stationary and movable parts is minimised. The co-rotating positioning of the processing unit also provides a possibility for autonomous operation of the rotor, in the case of possible interruptions of the communication with stationary parts.

In transformers, the electromagnetic process takes place between the primary and secondary windings. The windings are normally insulated, either by solid or liquid insulation material, which normally sets many of the limits in a transformer. Quantities measured directly in the vicinity of the windings positioned at high potential within its insulation are therefore the most interesting quantities. Temperature and voltages (including phase quantities) are important quantities to get hold of.

High-power electronics are today used among other things in power transmission systems for high-voltage direct current (HVDC, High Voltage Direct Current) or

compensators for reactive power regulation, the most occurring are SVC-devices (Static Var Compensators). Current converter connections for large powers are today mostly made with silicon based thyristors. These connections often demand large reactive powers as a result of that the currents of the alternating current network obtain large phase shift relative to its voltages. This means that the dimensioning of machines for current converter based systems and of current converters has to take reactive power flows into consideration, i.e. reactive losses in machines and reactances of the alternating current network and needs for phase compensation, thus not only to the pure active power flows with more or less negligible active losses.

The power electronics components are characterised by small dimensions and fast response, in particular concerning temperature and its derivative. The rated value concerning current depends e.g. of the temperature level in the semiconductor plate itself. Power capacitors as well as the high-voltage lead-throughs that are included in rotating electrical machines, power transformers, reactors and switching means, are both built by dielectric systems, in which the temperature, in particular at so-called "hot-spots", is essential in order to supervise and fully utilise the margins in the electric power objects.

The level regarding the temperature limits for semiconductors in power-electronic applications can be different depending on the temperature of the surrounding. As example can be mentioned a current limit for the electric power object of let us say 40 A at high surrounding temperature and let us say 50 A at lower surrounding temperature in order to utilise the temperature difference towards the surrounding. The possibility to position a temperature sensor directly at or in connection with the semiconductor can in this context further improve the possibility to utilise its full temperature range, by continuously measuring the temperature directly at the electric power object.

The present invention is based on that the control units and the supervision units at the different levels comprise "intelligent" means, which on one hand have certain processing or treatment capacity and on the other hand manage to communicate

with each other. The communication between different parts in the systems can be performed in different ways according to prior art and is preferably adjusted to the present needs. For communication, where among other things protection and defence compose an important part, a fast communication is appropriately selected, while communication of data of a more time neutral character can take place over slower media. The communication can thus be different in different parts of an electric power system. Suitable techniques for communication are radio, radio link, the telephony network, signal cables, fibre optical connections, Internet, intranet, satellite connections and communication via carrier frequency connections over the power lines.

In fig. 9 a sketch of a hierarchic system of control and supervision units is shown. For the purpose of clearness, a number of reference numerals for the same components have been omitted. A number of control units 42 communicate with a number of plant supervision units 32, which in turn is in contact with network supervision units 46. The structure can then continue upwards a number of levels. A control unit 42 thus has a communication link 72A, 72B to a plant supervision unit 32. This communication link 72A, 72B comprises an upward directed channel 74 and a downward directed channel 76. Even these channels can be of different type, since the type of data that is transported is different in the different directions. A communication link 72A between a specific control unit and a plant supervision unit can also be different from another communication link 72B from another control unit to the same or another plant supervision unit. A control unit can also have communication possibilities 75 with more than one plant supervision unit, or communication 77 directly with other control units. The present invention is best utilised if every control unit 42 that provides marginal critical quantities from places difficult to access has a possibility to a double directed communication in some way.

The same reasoning is also valid upwards in the hierarchy. Communication links can exist between supervision unit at different levels 80, 82 as well as between supervision units on the same level 78. In order for the system to operate satisfactory, also here a possibility for two-way information exchange between the different included supervision units is required. External data can also

advantageously be added to the system via an external link 81 at one or several levels.

The advantages concerning the operational management by the present invention arise mainly due to the availability of better input data, direct measured marginal critical quantities from places difficult to access in the electric power system. The access to real measured data, in contrast to calculated or estimated, creates a refined resolution. This in its turn influence functions such as optimum operation via for instance OPF (Optimal Power Flow), and functions for loss minimising, static operational security analysis and dynamic operational security analysis. The operational point can be controlled for creating suitable safe margins to technical limitations, e.g. thermal limits, voltage stability limits or transient stability limits. At the same time, one can create an economical optimum operation of the network, either by a centralised production planning or by a deregulated electric market where the price governs.

Since the measured data furthermore reflects the present actual situation, the present invention provides also a new dynamic dimension. In contrary to earlier operational optimisations, resources with dynamically varying capacity are now provided. Co-ordinated supervision of loads, where the access to internally measured data creates new possibilities concerning intelligent load control, from occasion to occasion.

Loss minimising based on actual data gives also environmental advantages by lower total losses in the electric power system. The present invention offers possibilities to a better dimensioning of components, i.e. a smaller size measured in MVA, by enabling an operational managing closer to the real present margins or limits. This as a result of the access to real measured data, in contrary to estimated ones. If one e.g. to a generator of 1,0 power units earlier has connected a transformer of 1.2 power units, one may now reduce the size by being able to supervise the condition in the transformer in a better way. The condition relates above all to the temperature of the active parts within the encapsulation and insulation. The transformer can instead

for instance be dimensioned for 1.1 power units. The smaller amount of material that is needed for this transformer thereby gives environmental advantages.

The invention facilitates the introduction of adaptive relay protections, which can include changes of the settings of the relay protections with regard to locally measured quantities from places difficult to access as well as based on input signals (from outside). Control signals that arrives from outside can be based on technical as well as economical judgements (or combinations of technical and economical). Resetting of relay protections enables an utilisation of available resources based on present margins, and not in advance set values. This should in most cases enable an increased transmission capability, but above all create a safer operation with regard to the present operational situation - and an improved protection of sensitive components in the network (direct measured values, not estimated). Adaptive relay protection in this application relates (in the first case) protections for individual electrical components such as for example electrical machines and transformers.

The present invention comprises preferably also a database creation. In earlier databases have mainly estimated operational data been used, estimated according to different models. Directly measured operational data from places difficult to access gives a considerably better decision foundation since the data is richer and more consistent. Databases should be present at different levels in the electric power system. In fig. 9, databases are indicated by the reference number 70, and databases of different kinds are thus preferably present in control units 42, plant supervision units 32 as well as network supervision units 46. The content in these databases may, however, differ considerably. In the control units 42, the databases comprise preferably data associated to different operational situations for the electric power object. The control units 42 may e.g. comprise historical databases that enable local control of the electric power object if an interruption occurs in the communication system. In contrary, control for instance regarding co-ordinated voltage regulation within an electric power plant is suitably performed via plant supervision units 32.

Corresponding control can be performed at different hierarchic levels in an electric power system. The need of local historical databases can be used in order to improve the control of parts of the electric power network if an interruption arises in the communication system. Interruptions in the transmission of information concerning the operation of the electric power system can arise at different levels in the electric power supervision system. These interruptions can depend on interruptions in the communication systems between different parts or in that certain parts of an electric power network electrically collapses, a so-called blackout. Two interesting cases can be exemplified by communication interruptions between individual electric power objects and its superior units or between one electric power plant and the rest of the electric power network.

As an example of the benefit of the invention at communication interruptions between an electric power plant and superior network supervision units, the possibilities to control the production of load in a subarea via the historical database of the network supervision unit in the isolated electric power plant or in the isolated part network can be mentioned. The subarea is from a communication point of view isolated from hierarchically superior network supervision units. By utilising locally available measurement values and stored information, a too conservative operation of machines and plant parts can be avoided until the point when the communications with superior network supervision unit can be guaranteed again. Another related example of a situation when historical databases can be utilised, is so-called island operation, when individual areas in the power system, often as a result of a large disturbance, operates autonomously during a time until the different island again can be synchronised.

During island operation, the stability and integrity of the entire system is often threatened, and if no fast measures are taken, also the separate network parts can collapse, i.e. a total collapse of the system. It can then be of a particularly large interest under controlled circumstances to systematically be able to overload certain electric power objects in order to save important loads in a part system during this critical phase. A good example of a load, to which there can exist interest to guarantee the supply of electric energy, is the medical service, at least during a

limited time period, even if this would result in that certain electric power objects are overloaded. By having access to directly measured data from these electric power objects, an improved balancing can be made between the need for securing the important load and the risks by overloading the object. It can at such occasions be a relatively large tendency to sacrifice a part of the life of the electric power object if this can be performed without risk for attendant damage and other serious consequences for the environment, in any case if it can lead to that important loads can be supplied in a safe manner.

Advantages with the access to directly measured data from places difficult to access together with historical databases can furthermore be obtained at interruptions in the communication between a single electric power object and its superior supervising unit. A problem with conventional machine protections and machine limiters according to prior art is that they in many cases are based on rough static models about loss generation and loss conduction and temperature rise. In order for a protection to be obtained also for rather extreme conditions, large safety margins have to be used, and furthermore, the actual conditions such as variation in the temperature of the surroundings are considered very little. A rotating machine is according to the invention appropriately equipped with both a rotating and a stationary processing unit in order to collect measurement data from the stator as well as the rotor, which in this context is a place difficult to access. The new possibilities for collection and processing of measurement data creates clearly improved conditions concerning autonomous operation of the machine at disturbances in the electric power system as well as the communication system.

At normal operation, locally measured data and from the external entering control signals based on other technical, economical, environmental and/or administrative information influence how the object is controlled. As soon as the communication with external supervision units is broken, it becomes more difficult to co-ordinate the operation of the object with other electric power objects. At, for instance, communication interruptions between the electric power object and its superior units, an improved autonomous control of the object can be obtained by the invention in relation to the technology of today. This autonomous control is in the case with a

rotating machine based on, directly via the stationary and/or co-rotating processing units of the machine, measured data in combination with data concerning the properties of the machine and operational conditions and status stored in historical databases in connection with the machine. For instance, an autonomous operating generator can be utilised for scheduled (co-ordinated) voltage regulation, at least during limited periods of time, and until the communication system is reinstated. This can be achieved e.g. by combining information about present time and day of the week with information about earlier control during similar conditions stored in the database and extrapolated data from the operation of the electric power object before the disturbance. This may also include a locally controlled overload of an autonomously operating generator, which also may help in maintaining the voltage stability in the electric power network.

A further example of autonomous control can be constituted by a co-ordinated utilisation of reactive resources in an isolated electric power network. Assume that an area has become electrically isolated after a disturbance and that there is a lack of reactive power. Generally, power electronics can be overloaded during a relatively short time in relation to electric machines. There might, however, be an interesting potential to immediately after the disturbance utilise the power electronics as much as it is possible by measuring the temperature directly at the semiconductor circuit and utilise the presently available temperature margin in order to so to say "buy time" in order to manage to carry through other measures, and in such a way reduce the risk for a more extensive disturbance.

The measures that are taken in the isolated electric power network is based on collection of present data from different electric power objects and the information is suitably co-ordinated in a network supervision unit present in the part network. At normal operation, the main tasks of the network supervision unit is to guarantee a reliable and economically optimum operation of the network, while it during disturbances of the described type changes over to prioritise operation safety aspects. By for instance reducing the active power output, additional space for reactive power production in connected synchronous generators can be created, which may help to maintain the voltage regulation and supply the most important

loads until the part network once more can be synchronised with the rest of the electric power system. This may, however, lead to increased costs, for instance by delivery reliability agreements with customers. By being able to supervise the actual temperature in the stator as well as the rotor, the possibilities for a co-ordinated and controlled overload of the machines are improved, which can be utilised in order to carry through additional reconnections and guarantee the supply of the most important loads in the isolated electric power network.

The created databases can also be used for technical supplementary services, for instance in the form of support at planning and pricing of production resources, voltage regulation, reactive reserves, frequency regulation and immediate and fast active reserves. Information about access to and pricing of support services (so-called ancillary services) is a relatively new request as a result of the creation of deregulated electrical markets. Access to information about how generators and other electric power objects have been loaded and how close to the limits they have been run and how much overload they may handle, respectively, is very interesting information in connection with the creation of such databases. Different interested parties will in this context have different, and sometimes competing, interests. As example can be mentioned differences in interests and requests concerning responsibility distribution between owners of production plants, owners of transmission resources and independent system operators. By collecting measurement data and building up this type of operational databases, a better overview of for instance the costs associated with reactive power production can be obtained. The access to directly measured operational data from places difficult to access constitutes a very important information source concerning the estimation of the real cost picture.

At a deregulated electrical market, it is not only network operators and owners of production plants and network stations that may be interested in this type of information, but also new market actors such as power brokers, independent power producers and separate energy service companies. The distribution of certain information achieves a value for the different market actors through the new possibilities to, for instance, charge for running an electric power object extra hard

during a certain period, and thus reduce its life. Thus, there is also an interest in limiting the rights for the different actors to take part of certain information. This may for instance be performed by the introduction of security keys (coding) in the used communication protocol. A well-reasoned utilisation of authorisation criteria may create a system with a satisfactory secrecy against unauthorised distribution of such information that may have an economic value.

An historical database with information about the operation at start and stop of e.g. an electric machine, combined with actual measured temperature data creates possibilities to calculate the real costs for stop and start of electrical machines. This information is in large parts lacking today, in particular for waterpower units. As a result of centralised production planning, it was earlier relatively unusual that, above all, water power units started and stopped several times a day. This will probably become more common as a result of the deregulation. The specific costs, increased wear etc., that this brings about are, however, often unclear for the owner of the unit. The combinations with new temperature data and historical databases makes it possible to obtain improved estimations of involved costs for start and stop of units.

Temperature data and levels of partial discharges (PD), measured primarily at places difficult to access, create an improved basis for planning of maintenance and reinvestments in existing plants, and improved estimations of the life of the components. By the present invention, knowledge about e.g. which temperatures that windings in a rotor and transformer windings really have been exposed for is provided. Earlier have only estimations of these temperatures been made by different more or less well-made thermal models of the components. Also the temperature in the stator is of interest. These real values may thereby be collected in a database and be utilised as a log of the thermal history. This creates possibilities to e.g. extract so-called "bath tub curves" for respective supervised component, which describes how the probability for faults is changed with the ageing of the component. Such bath tub curves state the fault frequency as a function of operation time and the access to reliable " bath tub curves " creates hereby improved possibilities to a good maintenance planning. The maintenance plans are then based on the real need and the knowledge about this can give a feedback to owners as well as

component manufacturers. Ageing phenomena and life can thus be continuously supervised, which reduces the need of maintenance. The lifetime supervision can also be used in order to be able to predict necessary reinvestments in a reliable way in advance. All told, this leads to a better capital administration, since very large amounts are invested in components in the electric power systems.

By the present invention, also a deliberate sale of lifetime is enabled. The access to a historic database with directly measured data from places difficult to access close to the real processes creates possibilities to supervise the "consumption" of lifetime. The influence on lifetime by overloading an electric component has to be estimated with regard to which temperature that has arisen and during how long time. This makes it possible for the owner of the plant to put a value on the "costs" or the "consumption", in the form of shortened lifetime for components in the plant, which arises in connection with allowing an overload during a certain time. One may thus put a price on the life time of components based on real costs and not solely estimates, which makes it possible to, in an intelligent way, "sell off the life time" of electrical components. The input signal from somewhere to ask for or demand access to overload capacity for any electric component can be based on the need of improved operational safety or motivated by economical terms, for instance increased transmission capacity. The basis for and the balancing between different types of needs, technical, economical or environmental, is in this context of subordinated importance, but can be seen forming a control signal. This control signal can be a request for access against compensation as well as a demand for access at risk for serious and more extensive consequences if the operational reliability can not be maintained.

Improved possibilities for preventive maintenance, by information about the condition in electrical equipment, including ageing phenomena, creates possibilities to an improved supervision and thereby an improved maintenance. Put together, this leads to improved capital management, based on better knowledge about the life time of the components. Maintenance planning can be based on actual operational conditions and directly measured data in the power network. A co-ordination can e.g. take place between the load output and the maintenance planning.

The state estimator constitutes an important part in the remote control system and is a basis for different decision foundation by describing the present state in the electric power system. The state estimation is thus a basic function for the more calculation-oriented functions that are included in the EMS/DMS systems. Basic reasons for the need of state estimation is the uncertainty in collected data caused by measurement uncertainties, that certain data can be missing from certain areas and that collected data simply can be erroneous as a result of any faults in any part of the chain from the sensor, via remote terminals and the communication system to the supervision units. It is of great importance to discover erroneous measurement data so that they do not influence decisions about measures at electric power objects or electric power plants. In a first step, unreasonable measurement data can be detected and sorted out for further analysis and processing.

The purpose with using estimation is to extract the best estimation about the present (actual) state in the power network from collected measurement data. The estimation can therefore be said to constitute a filtering of collected raw data from the electric power system. The systematic process concerning the filtering of raw data results in "losses" in information, which leads to that there is needed extra input data to the estimation process in order to completely determine the present state in the electric power network. Subsequently, there is a need for more measurement values than the number of unknown state variables that is included in the estimation. With unknown state variables are intended non-measured as well as measured but non-filtered (estimated) measurement values. The estimation can simplified be described as the solution of the overestimated equation system that arises when the number of measurement values exceeds the number of unknown state variables that has to be determined.

There is a multitude of different methods to carry through this state estimation (filtering) of collected measurement data, and an introduction is to separate static and dynamic methods. Static methods are primarily for determination of the power load. This in its turn is primarily intended to be used for studying static or slowly varying courses of events in the electric power system. Power flow data is

continuously provided by state estimation based on real time data, which are sent to the network supervision units and constitute the basis for most calculations that are performed in the control centres. Dynamic state estimation is, as the name states, related to transient or dynamic courses of events in the electric power network. This is used in cases where considerations should be taken to the dynamics of the components that are included in the electric power system. As example can be mentioned studies of co-operation between the turbine regulation and the frequency and voltage regulation belonging to generators.

The present invention gives also possibilities for an improved topology handling, in particular together with time labelling of data. By combining collection of measurement data from places difficult to access with an exact time label, measurement data can for instance be sorted in respect of data measured before and after a topology change, respectively. Such a topology change can for example be a fault that has led to that a switch has disconnected a line. This improves the possibilities to good estimation since the estimation is performed on only one topology and not by a mixture of measurement data belonging to different topologies.

The time labelling can for instance be based on the time signal from the GPS system (Global Positioning Satellite). The system consists of 24 satellites and can provide equipment with a time signal that is synchronised within 0.2 microseconds (μs) against a world standard time (UTC, Coordinated Universal Time). The utilisation of time labelling by utilising the time signal from GPS satellites is described at several places in the literature (se e.g. "Power system relaying" by S.H. Horowitz and A.G. Phadke, Research Studies Press Ltd & John Wiley & Sons Inc., pp. 287-289). By connecting this very accurate time labelling with collected measurement data, collected measurement data can be sorted in time order, careful comparisons can be performed and phase quantities calculated. In this context, it should be noted that this opens new and improved possibilities at the topology determination. The time signal of the GPS satellites has an accuracy of better than one microsecond, which if it is connected to the collection of measurement data creates possibilities to determine if a certain measurement value is collected before or after that an event has occurred.

One of the reasons for that time synchronised measurements data has become so interesting is the possibility to obtain corresponding phasor quantities from collected measurement data concerning alternating current quantities. In order to obtain phasor quantities, which represent the measurement value for alternating current quantities to both amount and phase angle and to be able to compare measurement values from different localisations in the electric power network, a very good time synchronisation is required. According the summary of "IEEE Standard for Synchrophasor for Power Systems" published in IEEE Transactions on Power Systems, Vol. 13, No. 1, pp. 73 - 77 (January 1998), a synchronising source for the time statement is required, with an accuracy (time resolution) of at least one microsecond in order to satisfy most demands put in an electric power system. This resolution corresponds to an accuracy in the angle determination of 0.018 degrees for a 50 Hz system and 0.022 degrees for a 60 Hz system, respectively. Synchronised measurement data collected for instance on different sides of a transformer can be used for relay protection functions. Collected and time synchronised measurement data would also be able to be used for adaptive relay protection setting.

A refined model building can also be obtained via the basis of the topology handling and data collection. The access to new operational data measured at places difficult to access and an improved topology handling gives possibilities to a dynamic updating of models included in the power system model. The access to new types of measurement data is particularly interesting, e.g. currents in damping windings in electrical machines, and improved topology handling by e.g. exact time labelling (GPS) of collected data. A reliable and good model building is particularly important since this model of the electric power system constitutes the basis for many other functions within the EMS/DMS group (operational reliability and operational safety). The collection of data to a network supervision unit creates possibilities to create a dynamically updated model of the electric power system. This is, however, nothing principally new against earlier used methods for data collection and topology determination. The unique for the present invention comes from the improved possibilities for collection of new <u>operational data</u> measured at places difficult to

access. As example can be mention collection of currents and voltages from direct measurement on the rotor in electrical machines. These new data can be utilised for dynamically updating parameters in models of the electric machine, which earlier in the best case were based on indirect measurements, for instance from the starting-up of the machine. A further interesting application is the possibilities to change parameters in the model based on the present, directly in the machine, measured temperature, which creates more exact models. If one furthermore uses the lifetime information that also is available by the historical database, ageing phenomena can also be included in the models.

The present invention also involves improvements concerning fault indications and the handling of faults. Improved possibilities for remote control can be based on combinations of locally measured quantities and global control signals. The access to measurement data from places difficult to access can furthermore discover fault states in the electric power network earlier, safer and more reliable than before. It is the immediate nearness to the electric/electromagnetic courses of events by the access to measurement data from places difficult to access that gives an improved picture concerning fault indications for the supervised electric power objects. Detection of e.g. damages on components or erroneous operational conditions in the electric power network can thereby be improved.

A drop-out of a slot in a rotor is an example of a fault case that now relatively easily should be detectable, which earlier would have been very complicated. Detection of fault states can now be made by direct measurement of operational data at places difficult to access. Examples on this are currents in damping windings and levels of partial discharges (PD) in electric machines, which also can be used to detect fault states in the network. Other new operational data that can be used for detection of fault states are vibrations, including resonance phenomena such as for instance ferro-resonance and SSR (sub-synchronous resonance), and measurement of overtones and asymmetric components (minus sequence and zero sequence) in electrical equipment. The possibilities for measuring and collecting information about overtones and asymmetric components in different equipment create besides a fault indication also improved possibilities for loss minimising at the operative operation.

Information about overtones, minus sequences and zero sequences also constitute a possibility to find problems and sources caused by electric quality problems.

Possibilities for remote manoeuvring based on information collected from now available measurement data, collected at places difficult to access in the electric power system, can be seen as an improvement of the fault handling system. By earlier described improved possibilities for topology determination by more exact time labelling by means of the GPS system, the possibilities to take correct measures at faults are improved. Remote manoeuvring can for instance be used for sectioning the network at operation changes, disturbances etc., which by means of the now available measurement data from so-called places difficult to access can lead to improved possibilities to overload components during (determined) time periods in a controlled way. The possibilities for overloading certain components in a co-ordinated and supervised manner leads to improved possibilities and may thereby create more time to carry out necessary reconnections after the occurrence of the disturbance, which leads to an improved operational reliability in the electric power system.

The communication between the different units comprises normally transferring of data and/or control information. In order to handle critical situations, the available communication capacity has to be dimensioned so that there during normal conditions is free capacity. Such free capacity can e.g. be utilised for downloading of software and/or retrieving of locally stored historical database information. Such information can be transferred in the time slots not utilised for data collection and communication of these data and control information between different units. Downloading of software may preferably occur in erasable PROM (Programmable Read-Only Memory), i.e. programmable ROM or "flash"-memories. Erasable Programmable Read-Only Memory (EPROM) - in particular UV Erasable PROM (EPROM) and Electrically Erasable PROM (EEPROM) - are useful, since these keep their memory content even during power losses.

In this context, it is important to guarantee that downloading of software takes place with a lower priority than other more important information transfer. Downloading

should therefore only take place with free capacity without competition with control or data information. The downloading should also be associated with secrecy procedures in order to guarantee that only authorised units can have access to the software.

In the same way as the downloading of software can take place in time slots, the updating of databases between different network supervision units, plant supervision units and control units takes place in these time slots. With the purpose not to block more important traffic on the communication network, the utilised protocol for information transfer between the different units should include some type of blocking of the downloading of software and the updating of databases when the capacity is needed in order to guarantee a reliable and economically optimum network operation. Blocks with data for the downloading of software and the updating of databases can then preferably be given a lower priority and will thus not always be sent immediately. Also in this context, it is important to guarantee that the updating of databases takes place with a lower priority than other more important information transfers. The updating should also be associated with a similar secrecy procedure as earlier discussed, in order to guarantee that only authorised units can have access to these data.

The need of information transferring can be limited by only transferring changes in measurement data or operational margins. This leads to a reduced need for transferring capacity, i.e. a lower need of performance of the communication system, which may result in that cheaper solutions can be used. If stationary conditions prevail, ideally no communication has to take place. The principles for how these changes should be communicated are stated in the protocols that are valid for the communication network. This is above all true for measurement values, which rarely are changed, or operational margins for larger units, where small changes do not come through within a short time. The reduced transfer-need can of course also be utilised for the downloading of software and the updating of databases mentioned above.

An important feature in a system according to the present invention is that information concerning the operation is spread all around in the system, in order to keep all information as updated as possible. The different nodes in the communication system, i.e. the supervision units and the control units also act as information filters. In a control unit, it can e.g. be interesting to have data concerning separate parts of an electric power object, e.g. the present shaft torque of a rotor, the level of partial discharges in the rotor or the present winding temperature of a transformer. For a plant supervision unit, this type of information can still be of interest, in particular if the processing capacity in the control unit is low. It is, however, often not an absolute necessity, but the control unit may very well supply the plant supervision unit by more summary information, but that still is based on the directly measured information. The control unit acts as an information filter that only lets information that is of importance to the receiver through. If one continues upwards in the hierarchic chain to a network supervision unit, too detailed information can often constitute an encumbrance. Here are probably only different types of summary operational margins for a whole plant of greatest interest. The plant supervision unit here acts to process the information received from the control units to margins that are valid for the plant as a whole.

It is not only the efficiency that controls which information that is exchanged. With a deregulation of the electric power networks, several independent actors are acting together. A part of the information can then be judged to be sensitive information that can be used in competing purpose. It is thus to prefer if the communication is provided with procedures that provides selective access and limited or controlled distribution of sensitive information. The information exchange between the network supervision unit and other units should take place in the form of messages, which besides address and message may comprise security keys in order to limit the right to take part of the information. By utilising different authorisation criteria for different units in the communication system, a satisfactory secrecy against unauthorised distribution of information can be achieved. The possibility of determining which information each utiliser has access to reduces the risk for unauthorised distribution of sensitive information and enables for instance that co-operation partners can have access to more information than other totally external parties.

In fig. 10, a flow diagram is illustrated, which represents a method according to one aspect of the present invention. The process begins in step 100. In step 101, a direct measurement is performed of at least a first marginal critical quantity at a first place difficult to access at a first electric power object. In step 102, in parallel with step 101, a direct measurement is performed of at least a second marginal critical quantity at a second place difficult to access at a second electric power object. The first and the second electric power object belong preferably to different object types. In step 103 and 104, respectively, the respective marginal critical quantities are processed to a first amount of data and a second amount of data, respectively. In the most trivial case, the first and/or the second amount of data may consist of the measurement values directly, whereby step 103 and/or 104 is totally excluded. In step 105 and 106, respectively, the amounts of data are transferred to a supervision unit. The supervision unit uses in step 108 the transferred amounts of data in order to estimate different present actual operational margins for the plant or network, in which the electric power objects are included. In step 110, the electric power plant or network is controlled based on at least one of the estimated present actual operational margins.

By descending one level in the measuring at the objects, one may receive a new type of dynamics in the system. By furthermore utilising this dynamics in several electric power objects, interesting advantages are achieved, mainly concerning control and protection. By then distributing this achieved dynamics upwards and outwards in the systems, one may furthermore design overall operational management, planning, estimation and modelling in a more sophisticated manner. The dynamics, which originally is achieved in direct contact with the effective electric power processes, will transmit infection to all parts of the supervision systems, and implies refined possibilities of remote supervision.

One skilled in the art realises that different modifications and changes can be made to the present invention without departing from the scope of the invention, as defined by the enclosed patent claims.

CLAIMS

1. Method for remote control of electric power system, comprising the steps of:

first direct measuring of at least a first marginal critical quantity at a first place difficult to access at a first electric power object (10, 12, 14; 40);

second direct measuring of at least a second marginal critical quantity at a second place difficult to access at a second electric power object (10, 12, 14; 40);

which places difficult to access are selected among following places:

at rotating part,

at high potential in small spaces, and

at high potential inside capsulation with solid or liquid insulation;

which second electric power object (10, 12, 14; 40) is of a kind different from the first electric power object (10, 12, 14; 40);

first transferring of a first amount of data, associated with said first marginal critical quantity, to a first supervision unit (32; 46) for a first electric power unit (1; 2; 2'; 2"), in which the first electric power object (10, 12, 14; 40) and the second electric power object (10, 12, 14; 40) are comprised;

second transferring of a second amount of data, associated with said second marginal critical quantity, to the first supervision unit (32; 46);

first estimating of the present operational margin of the first electric power object (10, 12, 14; 40) and second estimating of the present operational margin of the second electric power object (10, 12, 14; 40) by processing of data associated with said marginal critical quantities; and

controlling the first electric power unit (1; 2; 2'; 2") based on said present operational margins.

2. Method for remote control of electric power plant according to claim 1, **characterised in that** the first marginal critical quantity and the second marginal critical quantity are selected from the group of:

temperature;

load angle;

phase angle;

slip;

current;

voltage;
frequency; and
torque.

3. Method for remote control of electric power system according to claim 2, **characterised in that** at least one of the first marginal critical quantity and the second marginal critical quantity also is a material critical quantity, selected from the group of:

temperature; and
current.

4. Method for remote control of electric power system according to claim 1, 2 or 3, **characterised in that** the first electric power object (10, 12, 14; 40) and the second electric power object (10, 12, 14; 40) is of an object type selected from the group of:

electric machines;
transformers;
capacitors;
reactors; and
power electronics.

5. Method for remote control of electric power system according to claim 4, **characterised in that** the object type of the first electric power object is different from the object type of the second electric power object.

6. Method for remote control of electric power system according to any of the claims 1 to 5, **characterised in that** said operational margins comprise at least one of the following margins:

operational margin at stationary operation;
operational margin during limited predetermined time; and
operational margin during predetermined conditions.

7. Method for remote control of electric power system according to claim 6, **characterised in that** the predetermined condition comprises at least one of the following statements:

planned operational course;

disturbed operational conditions;

changes in production and load; and

price.

8. Method for remote control of electric power system according to any of the claims 1 to 7, **characterised by** at least one of the further steps of:

first processing of results from the first direct measurement for creation of the first amount of data; and

second processing of results from the second direct measurement for creation of the second amount of data.

9. Method for remote control of electric power system according to claim 8, **characterised in that** at least one of the first amount of data and the second amount of data comprises one of said operational margins.

10. Method for remote control of electric power system according to any of the claims 1 to 9, **characterised in that** the control of the first electric power unit (1; 2; 2'; 2") comprises control of at least one of the first electric power object (10, 12, 14; 40) and the second electric power object (10, 12, 14; 40).

11. Method for remote control of electric power system according to any of the claims 1 to 10, **characterised in that** the control of the first electric power unit (1; 2; 2'; 2") comprises control of a third electric power object (10, 12, 14; 40), which is comprised in the first electric power unit (1; 2; 2'; 2").

12. Method for remote control of electric power system according to any of the claims 1 to 11, **characterised by** the further step of:

third transferring of a third amount of data, associated with at least one of the first amount of data and the second amount of data, to a second supervision unit

(32; 46) for a second electric power unit (2; 2'; 2"), in which the first electric power unit (1; 2; 2'; 2") is comprised.

13. Method for remote control of electric power system according to claim 12, **characterised by** the further step of:

third processing of at least one of the first amount of data and the second amount of data for creation of the third amount of data.

14. Method for remote control of electric power system according to claim 12 or 13, **characterised by** the further step of:

control of the second electric power unit (1; 2; 2'; 2"), based on the third amount of data.

15. Method for remote control of electric power system according to claim 14, **characterised in that** the control of the second electric power unit (2; 2'; 2") comprises control of a third electric power unit (1; 2; 2'; 2"), which is comprised in the second electric power unit (2; 2'; 2").

16. Method for remote control of electric power system according to any of the claims 1 to 11, **characterised in that** the first transferring comprises the steps of:

third transferring of the first amount of data, to a second supervision unit (32; 46) for a second electric power unit (1; 2; 2'; 2"), in which the first electric power object (10, 12, 14; 40) is comprised, which second electric power unit (1; 2; 2'; 2") is comprised in the first electric power unit (2, 2', 2");

fourth transferring of a third amount of data, associated with the first amount of data, to the first supervision unit (32; 46).

17. Method for remote control of electric power system according to claim 16, **characterised by** the further step of:

third processing of the first amount of data for creation of the third amount of data.

18. Method for remote control of electric power system according to claim 16 or 17, **characterised by** the further step of:

controlling the second electric power unit (1; 2; 2'; 2"), based on the first amount of data.

19. Method for remote control of electric power system according to claim 18, **characterised in that** the controlling of the first electric power unit (2, 2', 2") comprises controlling the second electric power unit (1; 2; 2'; 2").

20. Method for remote control of electric power system according to any of the claims 16 to 19, **characterised in that** the controlling of the first electric power unit (2; 2'; 2") comprises controlling a third electric power unit (1; 2; 2'; 2"), which is comprised in the first electric power unit (2; 2'; 2").

21. Method for remote control of electric power system according to any of the claims 1 to 20, **characterised in that** at least one of the direct measurements also comprises measurement of pure material critical quantities selected from the group of:

partial discharges;
vibrations;
overtones;
minus sequence;
zero sequence;
rotational speed;
air gap fluxes; and
velocity.

22. Method for remote control of electric power system according to any of the claims 1 to 21, **characterised in that** at least one of the electric power units is an electric power network (2; 2'; 2") for generation, transmission, distribution or use of electric energy.

23. Method for remote control of electric power system according to any of the claims 1 to 22, **characterised in that** at least one of the electric power units is an electric power plant (1) for generation, transmission, distribution or use of electric energy.

24. Method for remote control of electric power system according to any of the claims 1 to 23, **characterised by** the further step of:

building of operational databases (70).

25. Method for remote control of electric power system according to claim 24, **characterised by** the further step of:

updating of databases (70) via the same communication paths (72A; 72B; 75; 77; 78; 80; 81; 82) that is used for data transferring.

26. Method for remote control of electric power system according to any of the claims 1 to 25, **characterised by** the further step of:

downloading of software via the same communication paths (72A; 72B; 75; 77; 78; 80; 81; 82) that is used for data transferring.

27. Method for remote control of electric power system according to any of the claims 1 to 26, **characterised in that** at least one of the transferring steps comprise at least one of the steps:

control of authorisation;

priority handling of data; and

secrecy handling.

28. Electric power system, comprising a first electric power unit (1; 2; 2'; 2") with a number of electric power objects (10, 12, 14; 40) and a first supervision unit (32; 46), **characterised in that**

at least a first electric power object (10, 12, 14; 40) comprises means (18; 22; 26) for direct measurement of at least one first marginal critical quantity at a first place difficult to access;

at least a second electric power object (10, 12, 14; 40) comprises means (18; 22; 26) for direct measurement of at least one second marginal critical quantity at a second place difficult to access;

which places difficult to access are selected among following places:

at rotating part,

at high potential in small spaces, and

at high potential inside capsulation with solid or liquid insulation;

which second electric power object (10, 12, 14; 40) is of a kind different from the first electric power object (10, 12, 14; 40);

first means for transferring a first amount of data, associated with said first marginal critical quantity, from the first electric power object (10, 12, 14; 40) to the first supervision unit (32; 46);

second means for transferring a second amount of data, associated with said second marginal critical quantity, from the second electric power object (10, 12, 14; 40) to the first supervision unit (32; 46);

means for estimation of the present operational margin of the first electric power object (10, 12, 14; 40) and for estimation of the present operational margin of the second electric power object (10, 12, 14; 40); and

in that the first supervision unit (32; 46) comprises means for controlling the electric power system based on said operational margin.

29. Electric power system according to claim 28, **characterised in that** the first marginal critical quantity and the second marginal critical quantity are selected from the group of:

temperature;

load angle;

phase angle;

slip;

current;

voltage;

frequency; and

torque.

30. Electric power system according to claim 29, **characterised in that** at least one of the first marginal critical quantity and the second marginal critical quantity also is a material critical quantity, selected from the group of:

temperature; and
current.

31. Electric power system according to claim 28, 29 or 30, **characterised in that** the first electric power object (10, 12, 14; 40) and the second electric power object (10, 12, 14; 40) is of an object type selected from the group of:

electric machines;
transformers;
capacitors;
reactors; and
power electronics.

32. Electric power system according to claim 31, **characterised in that** the object type of the first electric power object is different from the object type of the second electric power object.

33. Electric power system according to any of the claims 28 to 32, **characterised in that** said operational margins comprises at least one of the following margins:

operational margin at stationary operation;
operational margin during limited predetermined time; and
operational margin during predetermined conditions.

34. Electric power system according to claim 33, **characterised in that** the predetermined condition comprises at least one of the following statements:

planned operational course;
disturbed operational condition;
changes in production and load; and
price.

35. Electric power system according to any of the claims 28 to 34, **characterised by** at least one of the first electric power object (10, 12, 14; 40) and the second electric power object (10, 12, 14; 40) comprises means for processing of results from the direct measurement.

36. Electric power system according to any of the claims 28 to 34, **characterised in that** the first supervision unit (32; 46) comprises the means for estimation of the operational margins of the electric power objects.

37. Electric power system according to any of the claims 28 to 36, **characterised in that** the means for controlling the first electric power unit (1; 2; 2'; 2") comprises means for controlling at least one of the first electric power object (10, 12, 14; 40) and the second electric power object (10, 12, 14; 40).

38. Electric power system according to any of the claims 28 to 37, **characterised in that** the means for controlling the first electric power unit (1; 2; 2'; 2") comprises means for controlling a third electric power object (10, 12, 14; 40), which is comprised in the first electric power unit (1; 2; 2'; 2").

39. Electric power system according to any of the claims 28 to 38, **characterised by** a third means for transferring a third amount of data, associated with at least one of the first amount of data and the second amount of data, to a second supervision unit (32; 46) for a second electric power unit (2; 2'; 2"), in which the first electric power unit (1; 2; 2'; 2") is comprised.

40. Electric power system according to claim 39, **characterised in that** the first supervision unit (32; 46) comprises means for processing of at least one of the first amount of data and the second amount of data.

41. Electric power system according to claim 39 or 40, **characterised in that** the second supervision unit (32; 46) comprises means for controlling the second electric power unit (1; 2; 2'; 2").

42. Electric power system according to claim 41, **characterised in that** the second electric power unit (2; 2'; 2") comprises a third electric power unit (1; 2; 2'; 2"), whereby the means for controlling the second electric power unit (2; 2'; 2") is arranged to control the third electric power unit (1; 2; 2'; 2").

43. Electric power system according to any of the claims 28 to 38, **characterised in that** the first electric power unit (2, 2', 2") comprises a second electric power unit (1; 2; 2'; 2"), which in turn comprises the first electric power object (10, 12, 14; 40) and a second supervision unit (32; 46), which first means for transferring is arranged for transferring the first amount of data to the second supervision unit (32; 46), which second supervision unit (32; 46) comprises a third means for transferring of a third amount of data, associated with the first amount of data, to the first supervision unit (46).

44. Electric power system according to claim 43, **characterised in that** the second supervision unit (32; 46) comprises means for processing the first amount of data.

45. Electric power system according to claim 43 or 44, **characterised in that** the second supervision unit (32; 46) comprises means for controlling the second electric power unit (1; 2; 2'; 2"), based on the first amount of data.

46. Electric power system according to claim 45, **characterised in that** the means for controlling the first electric power unit (2, 2', 2") is arranged to control the second electric power unit (1; 2; 2'; 2").

47. Electric power system according to any of the claims 43 to 46, **characterised in that** the first electric power unit (2; 2'; 2") further comprises a third electric power unit (1; 2; 2'; 2"), whereby the means for controlling the first electric power unit (2; 2'; 2") is arranged to control also the third electric power unit (1; 2; 2'; 2").

48. Electric power system according to any of the claims 28 to 47, **characterised in that** at least one of the electric power objects (10, 12, 14; 40) also comprises

means for direct measurement of pure material critical quantities selected from the group of:

partial discharges;
vibrations;
overtones;
minus sequence;
zero sequence;
rotational speed;
air gap fluxes; and
velocity.

49. Electric power system according to any of the claims 28 to 48, **characterised in that** at least one of the electric power units is an electric power network (2; 2'; 2") for generation, transmission, distribution or use of electric energy.

50. Electric power system according to any of the claims 28 to 49, **characterised in that** at least one of the electric power units is an electric power plant (1) for generation, transmission, distribution or use of electric energy.

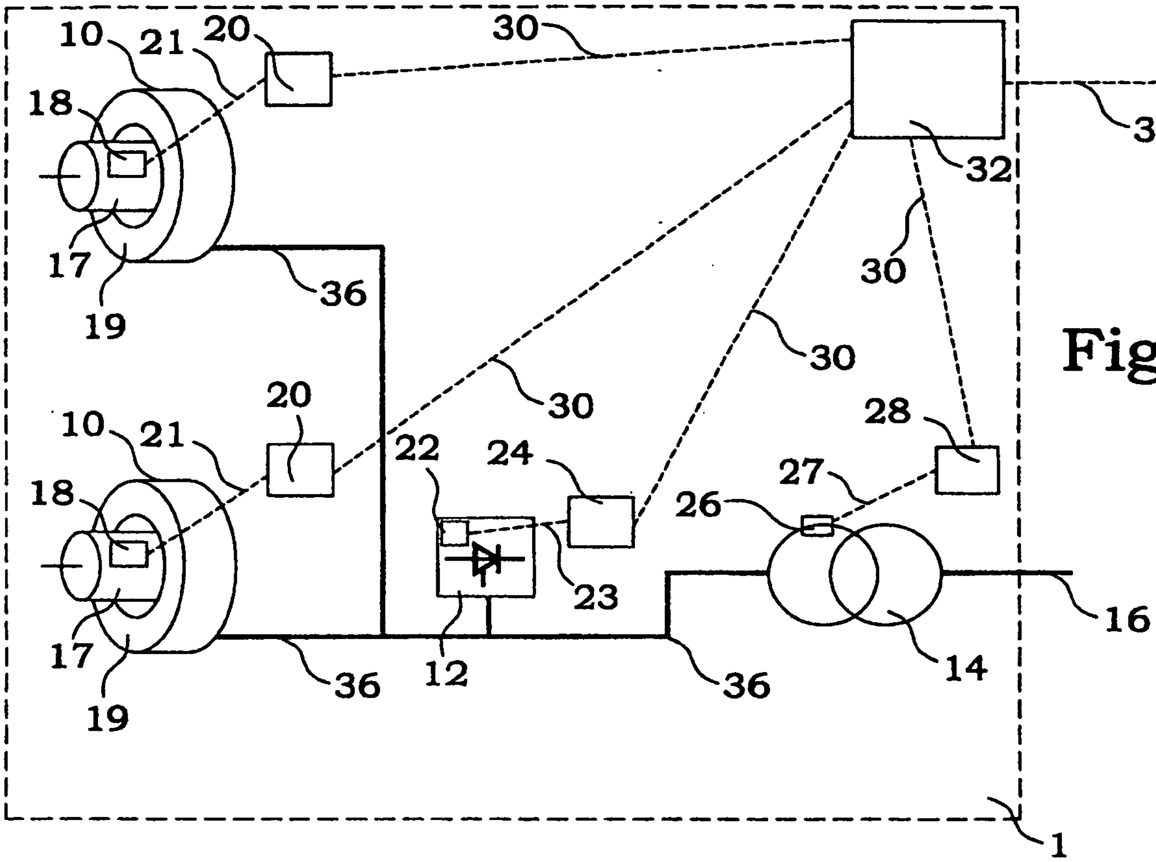
51. Electric power system according to any of the claims 28 to 50, **characterised in that** at least one of the supervision units (32; 46) and/or at least one of the electric power objects (10, 12, 14; 40) comprises an operation database (70).

52. Electric power system according to claim 51, **characterised by** means for updating the databases (70) via the same communication paths (72A; 72B; 75; 77; 78; 80; 81; 82) that is used for the data transferring.

53. Electric power system according to any of the claims 28 to 52, **characterised by** means for downloading software via the same communication paths (72A; 72B; 75; 77; 78; 80; 81; 82) that is used for the data transferring.

54. Electric power system according to any of the claims 28 to 53, **characterised by** at least one of the following means:

means for control of authorisation;
means for priority handling of data; and
secrecy handling means.



10
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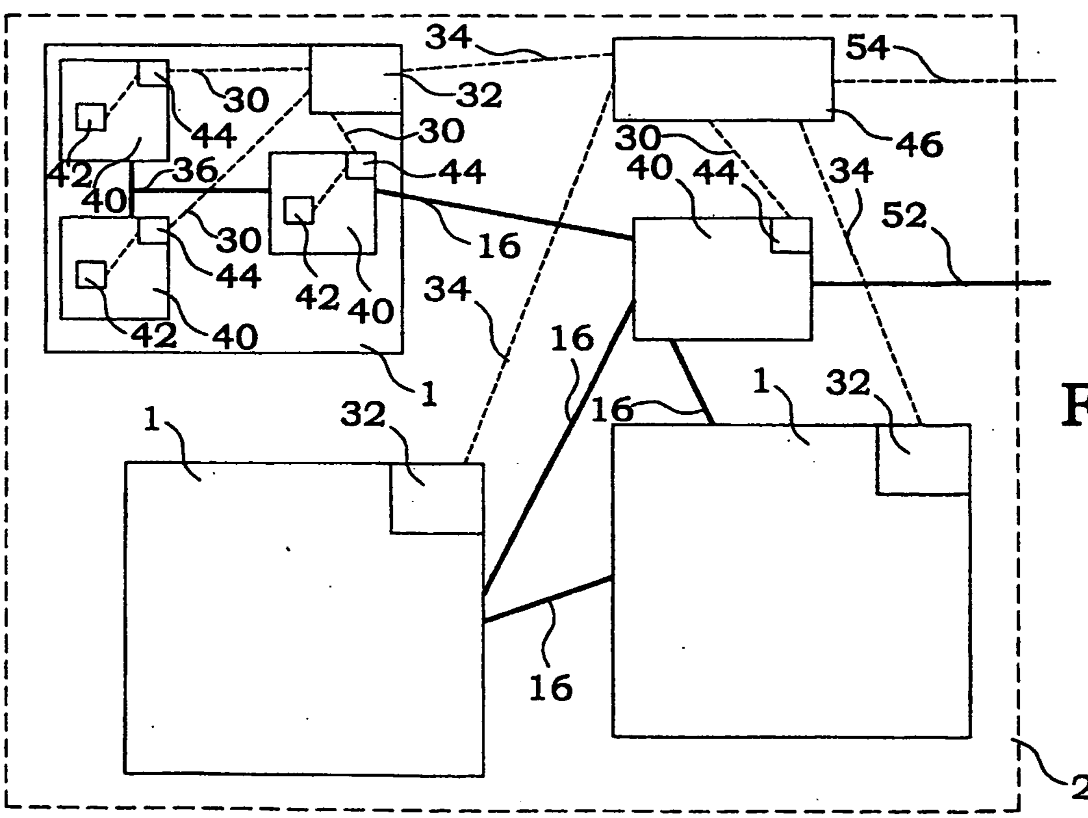
36
1

Fig. 1



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16
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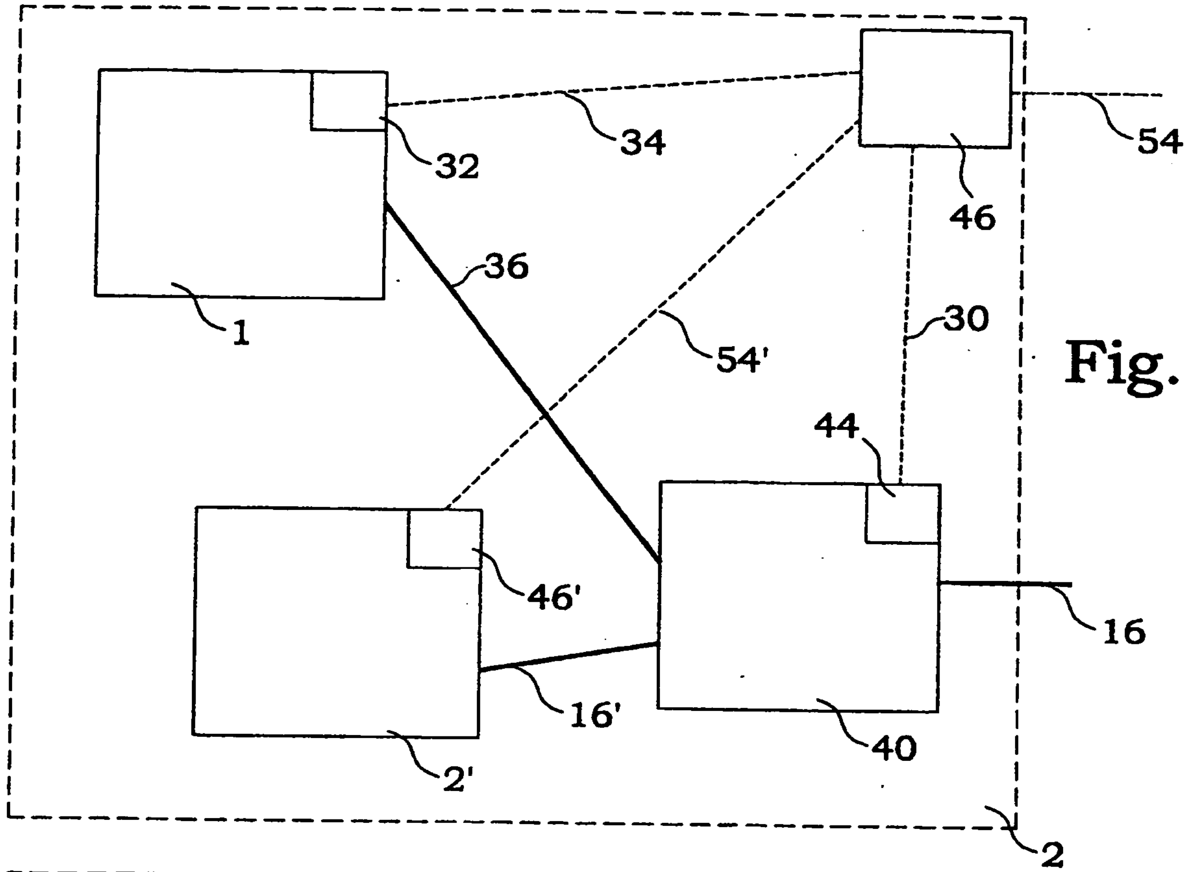
1
32
32
1
16
2

Fig. 2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36
1
30
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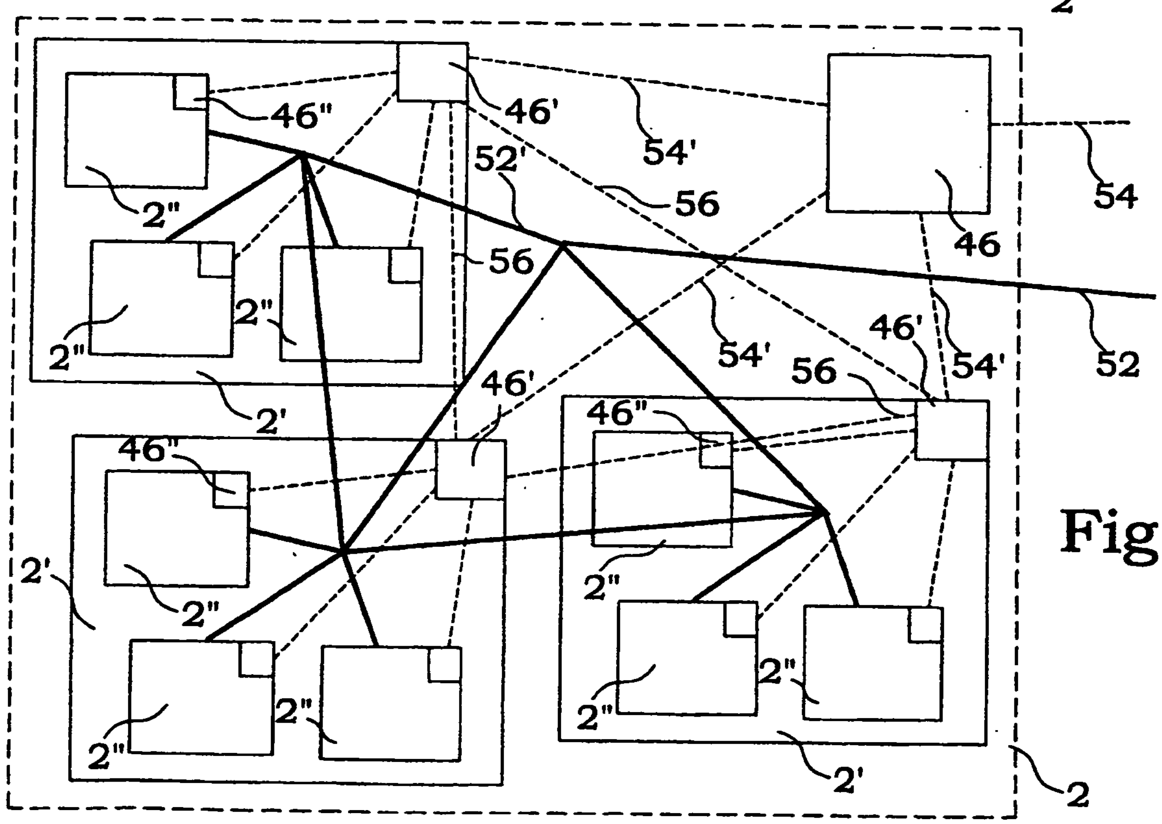
44
46'
16
16'
40
2'
2

Fig. 3


46"
46'
54'
54
52'
56
2"
46
56
2"
2"
54'
46'
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56
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2"
2'
2

Fig. 4

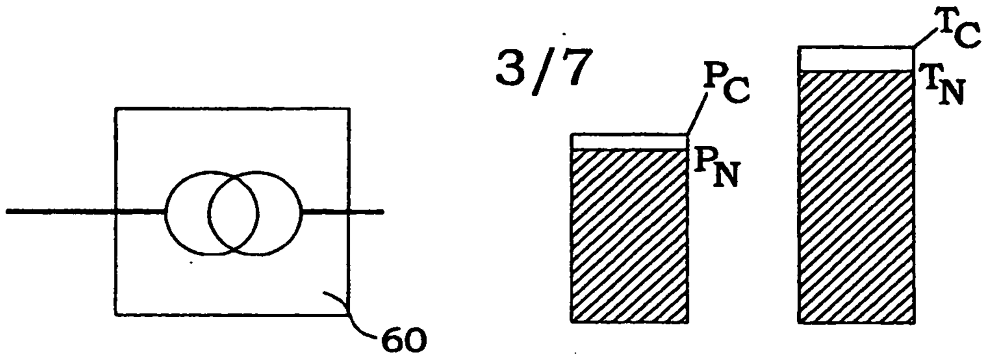


Fig. 5a

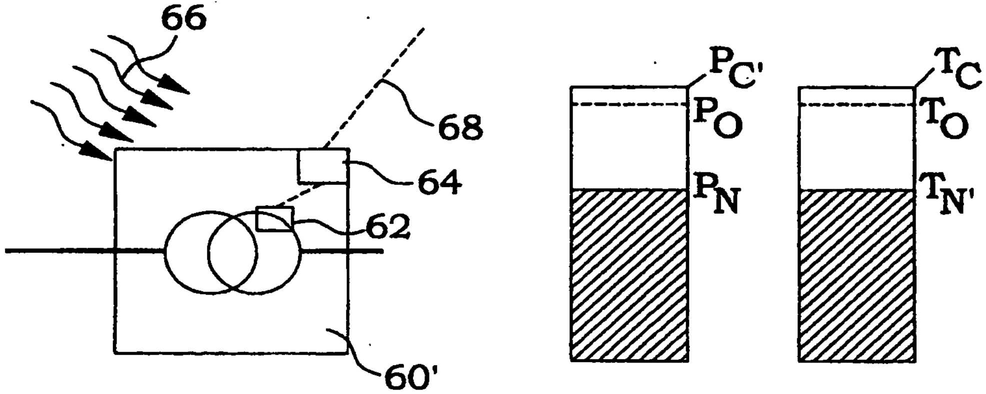


Fig. 5b

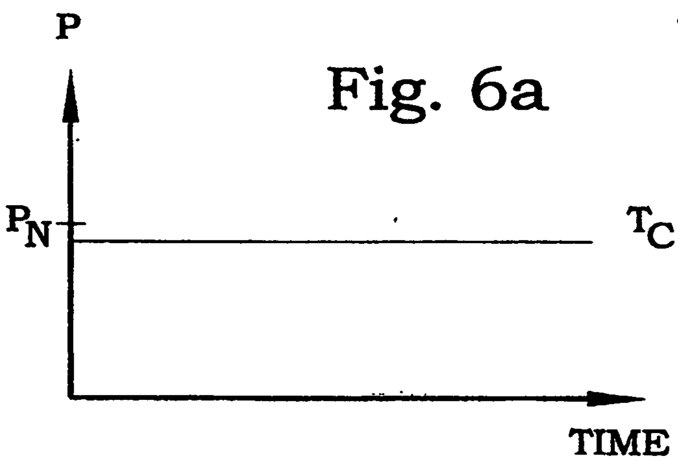


Fig. 6a

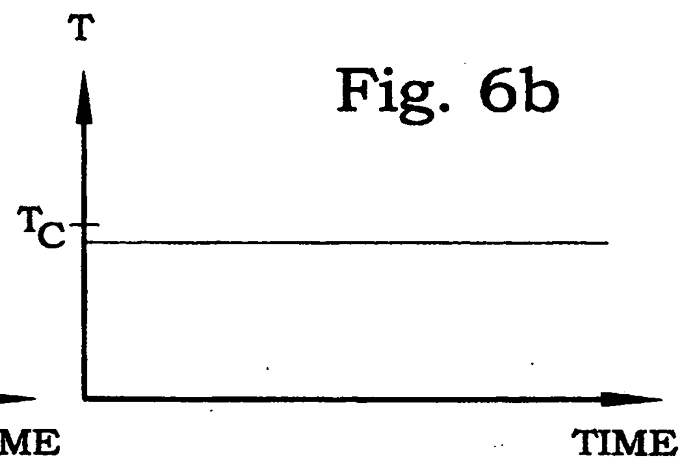


Fig. 6b

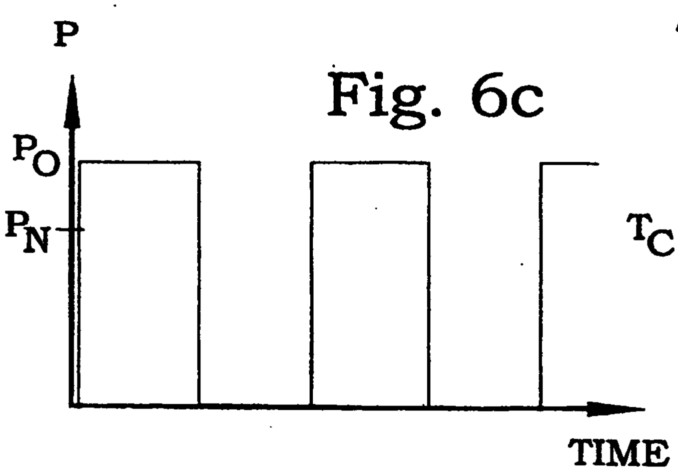


Fig. 6c

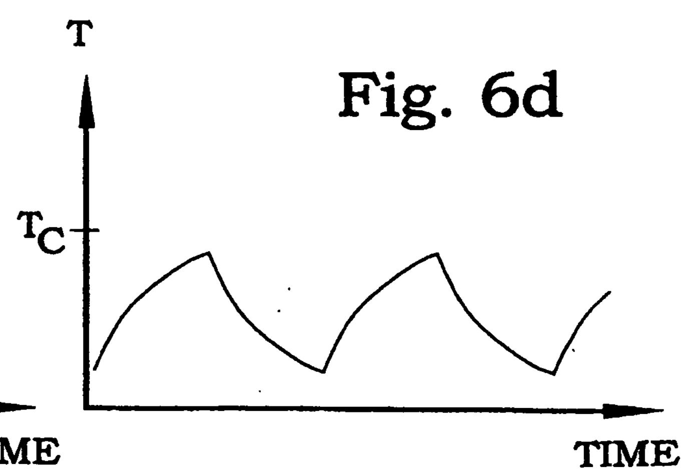
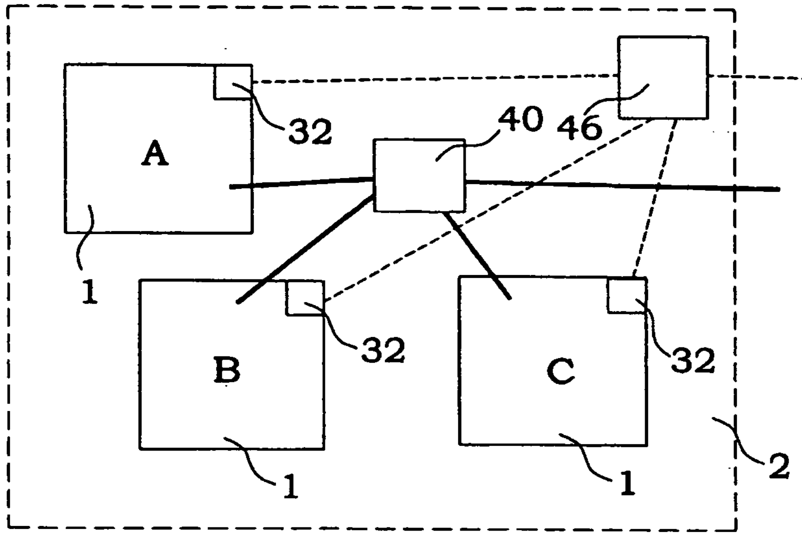


Fig. 6d

Fig. 7a



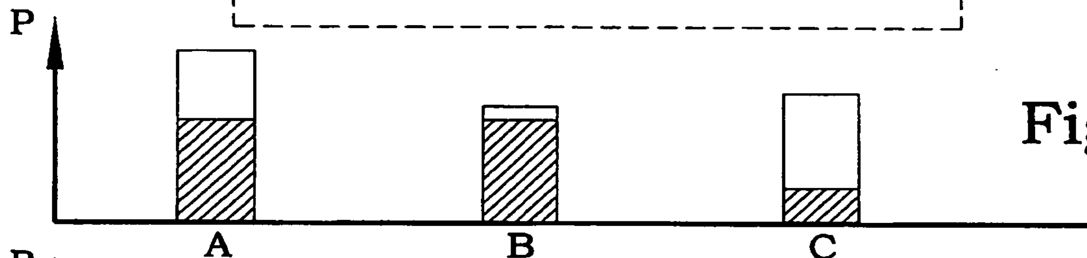


Fig. 7b

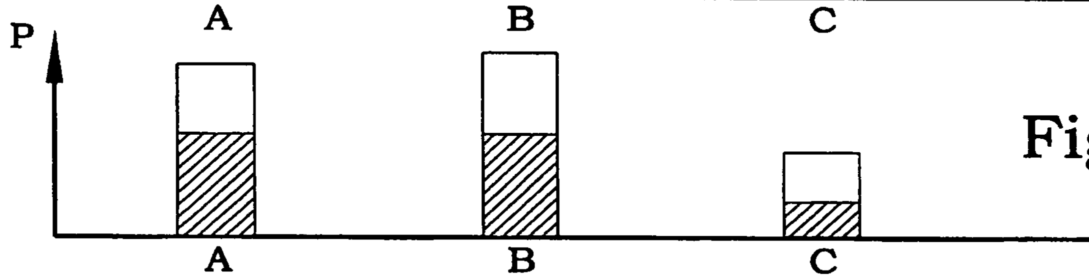


Fig. 7c

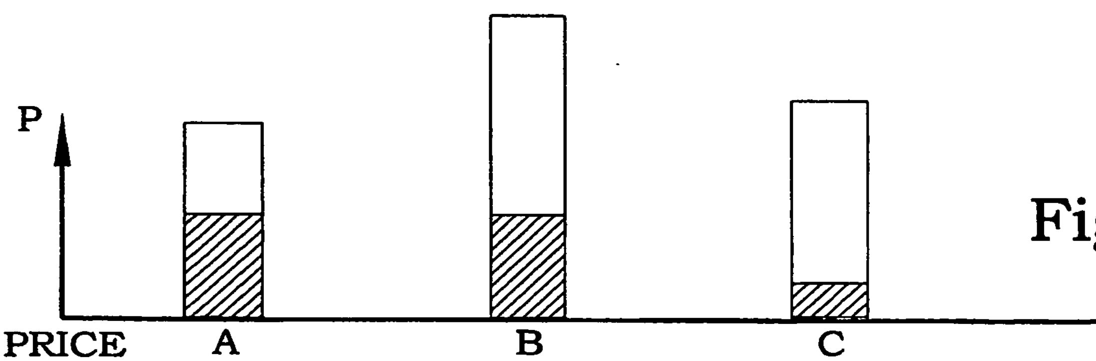


Fig. 7d

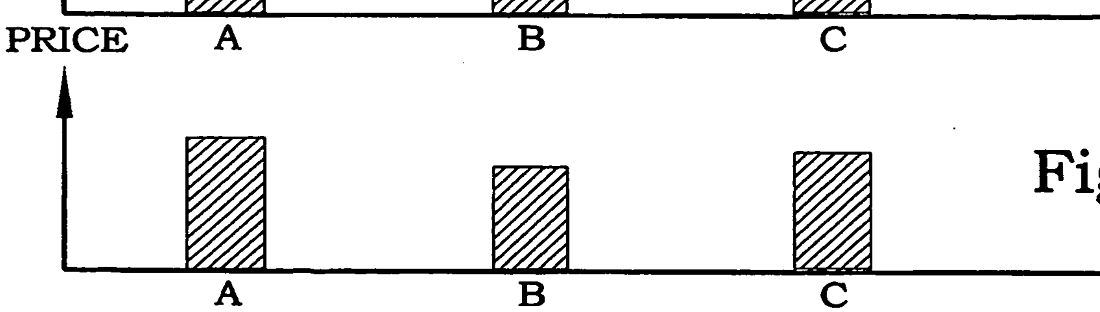
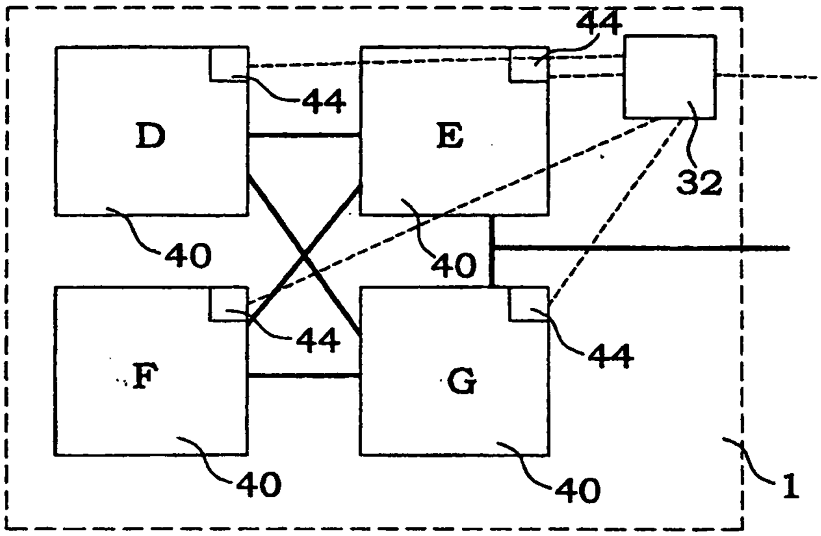


Fig. 7e

Fig. 8a



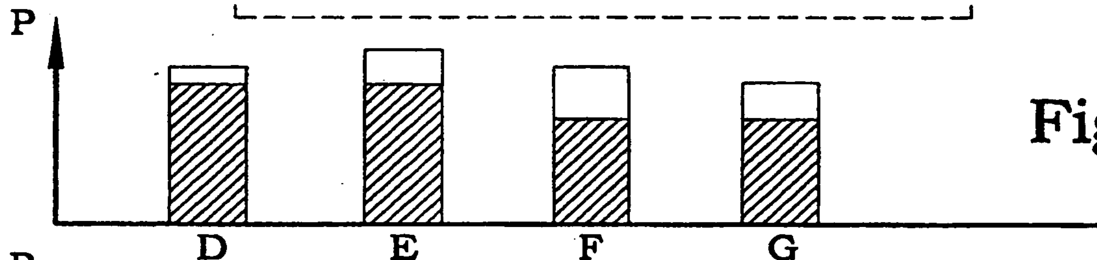


Fig. 8b

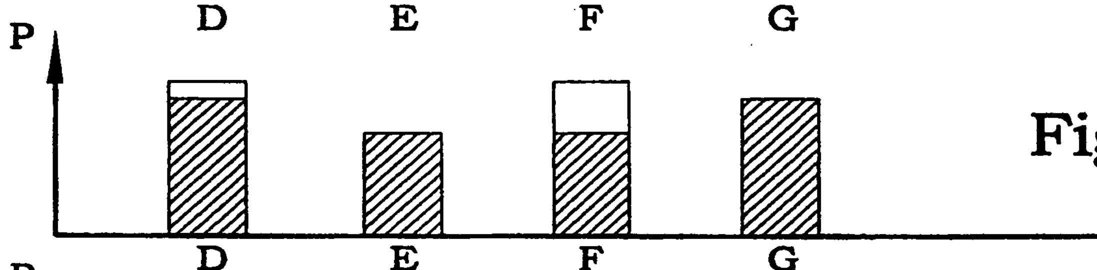


Fig. 8c

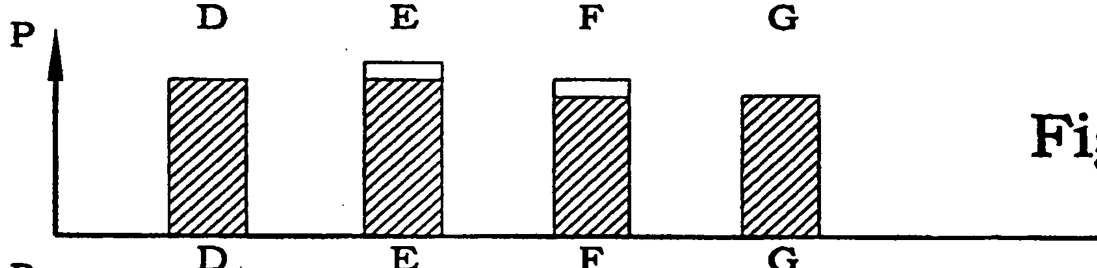


Fig. 8d

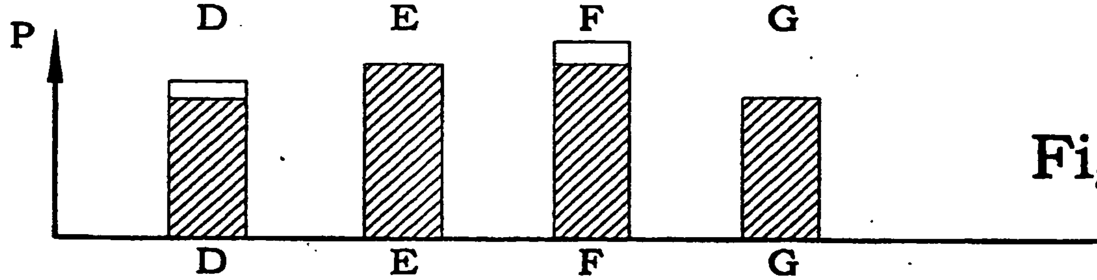
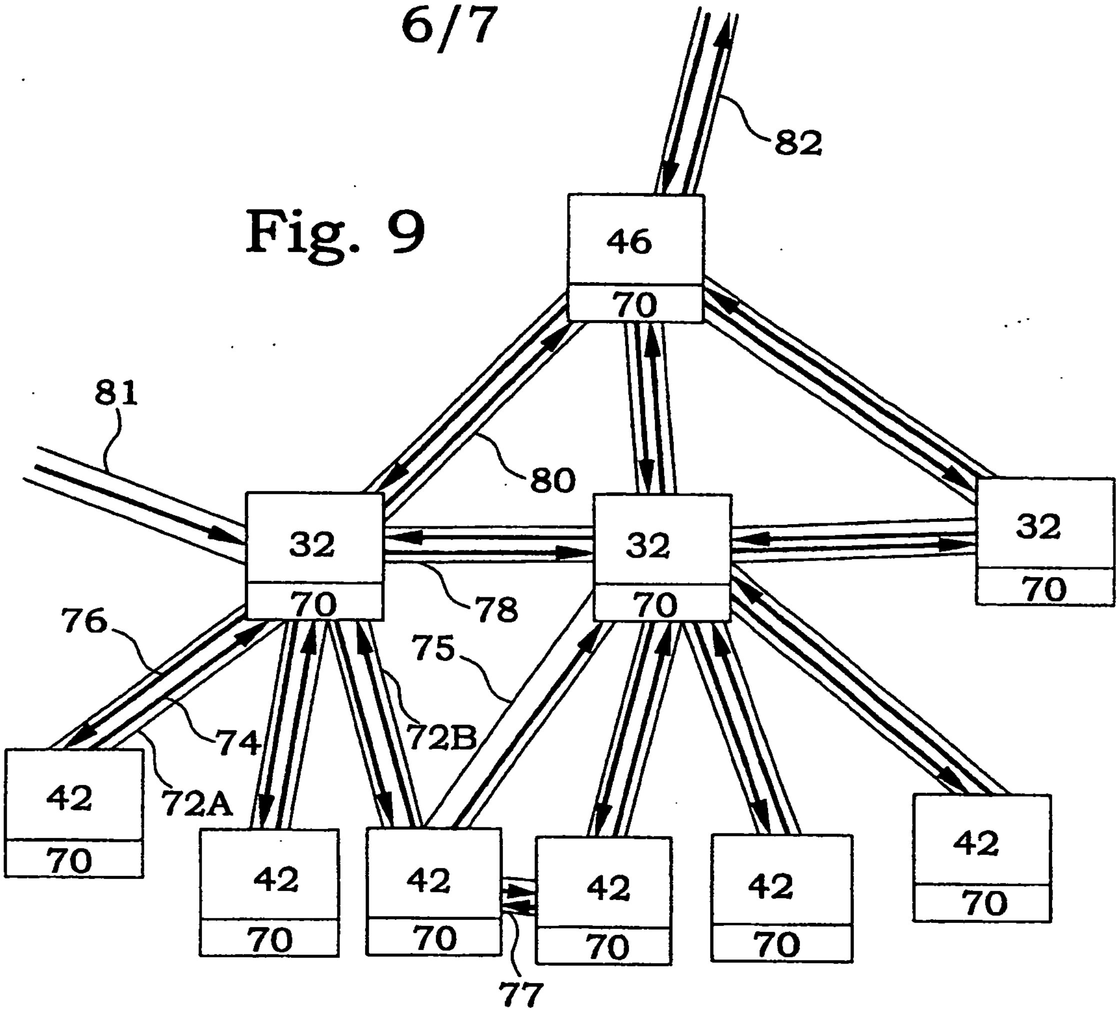


Fig. 8e

6/7

Fig. 9



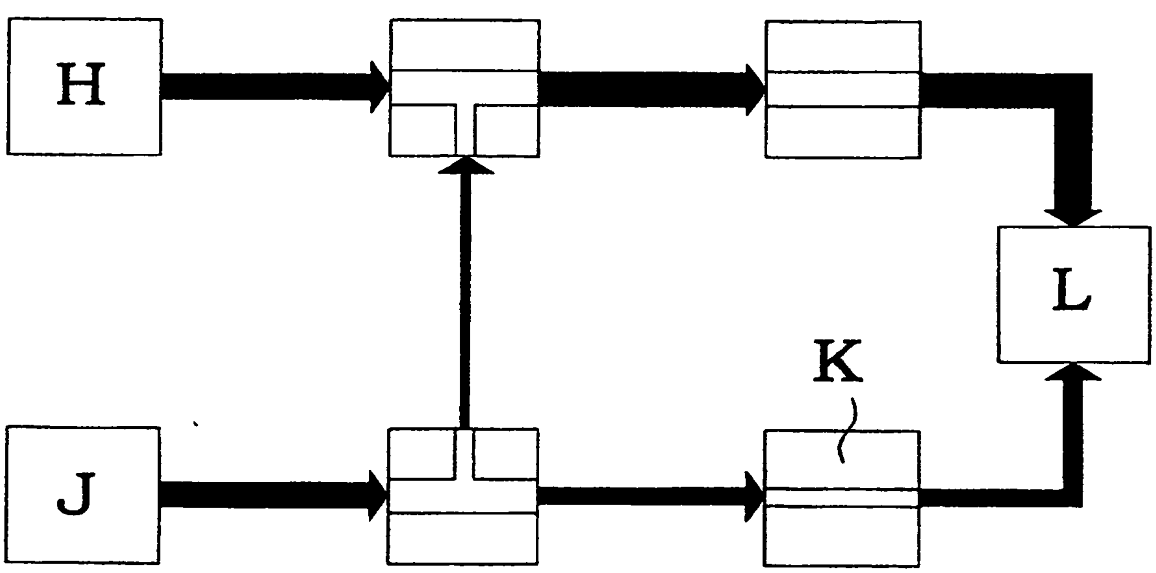


Fig. 11

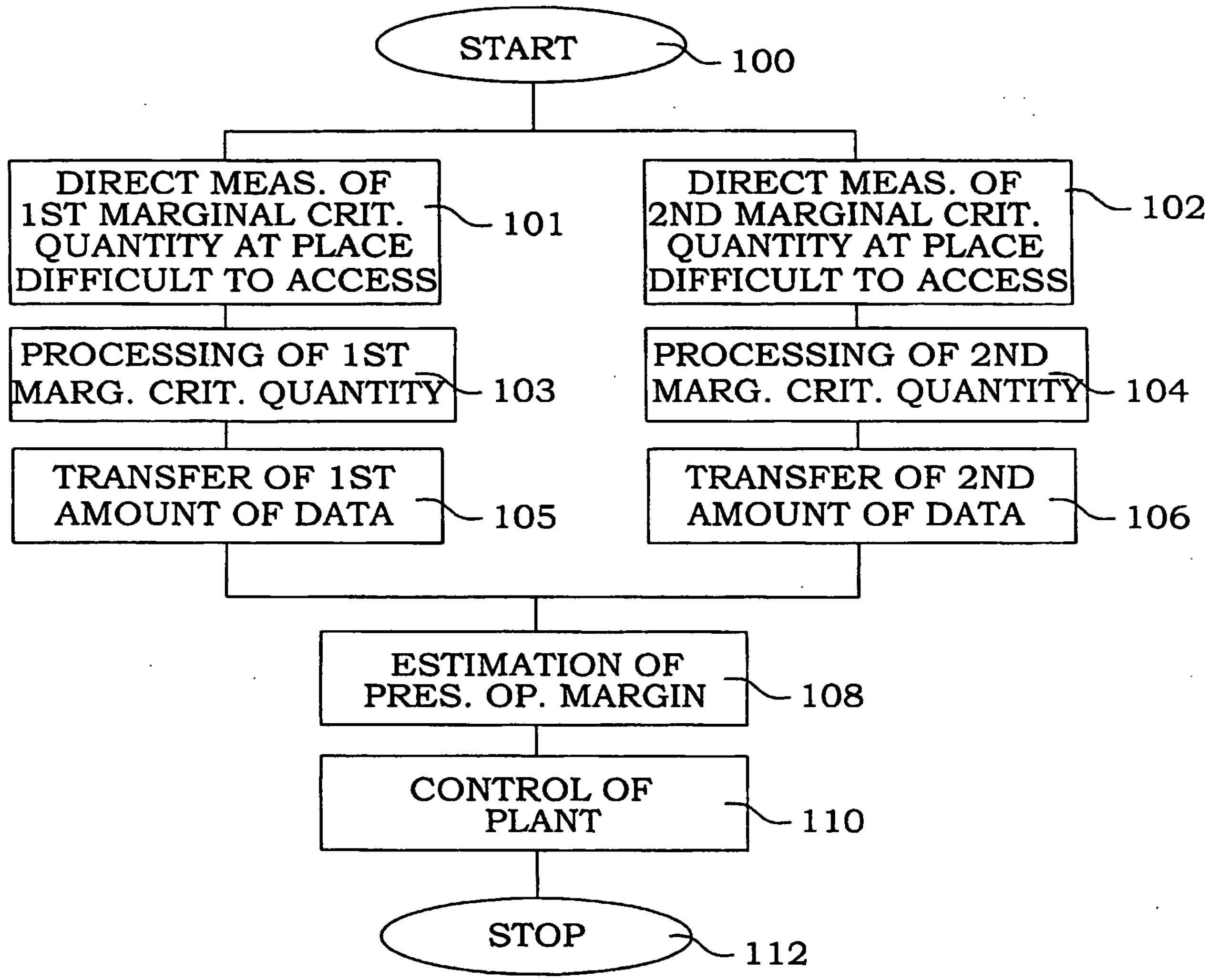

START
100
DIRECT MEAS. OF 1ST MARGINAL CRIT. QUANTITY AT PLACE DIFFICULT TO ACCESS
101
DIRECT MEAS. OF 2ND MARGINAL CRIT. QUANTITY AT PLACE DIFFICULT TO ACCESS
102
PROCESSING OF 1ST MARG. CRIT. QUANTITY
103
PROCESSING OF 2ND MARG. CRIT. QUANTITY
104
TRANSFER OF 1ST AMOUNT OF DATA
105
TRANSFER OF 2ND AMOUNT OF DATA
106
ESTIMATION OF PRES. OP. MARGIN
108
CONTROL OF PLANT
110
STOP
112

Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 00/01606

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H02J 13/00, H02P 9/00, H02P 13/00, G01K 7/00, H02H 7/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H02J, H02P, G01K, H02H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Elkrafthandboken, Elkraftsystem 1, kapitel 11, sid 305-324, kapitel 12, sid 326-332, ISBN 91-47-00064-3. --	1-54
Y	Elkrafthandboken, Elkraftsystem 2, kapitel 10, sid 391-404, ISBN 91-47-00065-1 --	1-54
Y	US 5257863 A (FRANK Y. CHU ET AL), 2 November 1993 (02.11.93), column 1, line 1 - line 31; column 1, line 52 - line 56, abstract --	1-54

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2000	02 -11- 2000

Name and mailing address of the ISA/
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3824857 A (FOREST D. SMITH), 23 July 1974 (23.07.74), column 1, line 1 - line 16; column 2, line 1 - line 14, abstract --	1-54
Y	US 4140999 A (WILLIAM H. CONWAY), 20 February 1979 (20.02.79), column 1, line 27 - line 46; column 1, line 56 - column 2, line 11, abstract --	1-54
Y	GB 1470692 A (SKODA), 21 April 1977 (21.04.77), column 2, line 62 - line 77 -- ---------	1-54

INTERNATIONAL SEARCH REPORT
Information on patent family members

03/10/00

International application No.
PCT/SE 00/01606

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5257863 A	02/11/93	NONE	
US 3824857 A	23/07/74	NONE	
US 4140999 A	20/02/79	NONE	
GB 1470692 A	21/04/77	CS 165150 B	28/11/75
		DE 2427830 A	09/01/75